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Master Thesis

A Text Mining Based Assessment of Business Fields within the German Energy Market

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Hereby I declare that I wrote this thesis myself with the help of no more than the mentioned literature and auxiliary means.

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Abstract

Major changes have been underway in the German energy market, influenced by a variety of factors. The liberalisation of European energy markets, the phasing out of nuclear energy and the implementation of new technologies, and the increased drive to move towards a carbon neutral, sustainable economy have all played significant roles in changing the landscape of the German energy market. This study investigates the extent to which the various business fields that exist within the German energy market are represented in the language used on the websites of companies that are active within this market and how this has changed in the 10 year period from 2010 to 2019.

To achieve the aims set out in this thesis, the text from over 5000 websites is examined and categorised according to the level of representation on each website of each of 17 business model classes identified as making up the energy sector. A thesaurus based approach to text categorisation is used that involves the creation of a business model thesaurus which is divided into different sections, each corresponding to a business model class and populated by terminology associated with that class. This thesaurus and the terminology contained within it is then used to categorise the text data from company websites based on the frequency with which terminology in the thesaurus appears amongst the text data.

The results of this process show that the business model class that was by far the most likely to be reflected in the language used by companies on their websites was that which was related to the large scale production of electricity from renewable sources. There was also a general decline throughout the decade in the use of language relating to the class pertaining to use of energy derived from conventional means. In general, language related to those business model classes that were associated with the provision of services appeared frequently amongst the text data and the second half decade saw a notable increase in the use of language relating to the provision of software. On a regional level there was a tendency towards greater stability amongst the more economically developed of the German federal states, while greater fluctuations in the levels of representation of the different business model classes could be observed in the city states and often in the states of the former German Democratic Republic.

Zusammenfassung

Der deutsche Energiemarkt befindet sich in einem tiefgreifenden Wandel, der durch eine Vielzahl von Faktoren beeinflusst wird. Die Liberalisierung der europäischen Energiemärkte, der Ausstieg aus der Kernenergie und die Einführung neuer Technologien sowie das verstärkte Streben nach einer CO2-neutralen, nachhaltigen Wirtschaft haben die Landschaft des deutschen Energiemarktes maßgeblich verändert. Diese Studie untersucht, inwieweit die verschiedenen Geschäftsfelder innerhalb des deutschen Energiemarktes in der Sprache auf den Websites von Unternehmen repräsentiert sind, die in diesem Markt aktiv sind, und wie sich dies in dem 10-Jahres-Zeitraum von 2010 bis 2019 verändert hat.

Um die in dieser Arbeit gesetzten Ziele zu erreichen, wird der Text von über 5000 Websites untersucht und entsprechend dem Grad der Repräsentation jeder der 17 Geschäftsmodellklassen, die den Energiesektor ausmachen, auf jeder Website kategorisiert. Es wird ein thesaurusbasierter Ansatz zur Textkategorisierung verwendet, der die Erstellung eines Geschäftsmodell-Thesaurus beinhaltet, der in verschiedene Abschnitte unterteilt ist, die jeweils einer Geschäftsmodellklasse entsprechen und mit der zu dieser Klasse gehörenden Terminologie gefüllt sind. Dieser Thesaurus und die darin enthaltene Terminologie wird dann verwendet, um die Textdaten von Unternehmenswebsites anhand der Häufigkeit zu kategorisieren, mit der die Terminologie im Thesaurus in den Textdaten erscheint.

Die Ergebnisse dieses Prozesses zeigen, dass sich die Geschäftsmodellklasse, die sich auf die großtechnische Erzeugung von Strom aus erneuerbaren Quellen bezog, mit Abstand am häufigsten in der von Unternehmen auf ihren Websites verwendeten Sprache wiederspiegelte. Es gab auch einen allgemeinen Rückgang in der Verwendung von Sprache in Bezug auf die Klasse, die sich auf die Nutzung von Energie aus konventionellen Mitteln bezog, während des gesamten Jahrzehnts. Im Allgemeinen tauchten in den Textdaten häufig Begriffe auf, die sich auf die Geschäftsmodellklassen bezogen, die mit der Bereitstellung von Dienstleistungen verbunden waren, und in der zweiten Hälfte des Jahrzehnts gab es einen bemerkenswerten Anstieg der Verwendung von Begriffen, die sich auf die Bereitstellung von Software bezogen. Auf regionaler Ebene zeigte sich eine Tendenz zu größerer Stabilität in den wirtschaftlich entwickelteren Bundesländern, während in den Stadtstaaten und häufig in den Ländern der ehemaligen DDR größere Schwankungen in der Repräsentanz der verschiedenen Geschäftsmodellklassen zu beobachten waren.

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1 Introduction

1.1 Motivation - A New Generation of European Energy

As the second millennium of the Common Era drew to a close the decision was made within the EU to liberalise the European energy markets. Technical, economical and political changes within the EU at this time had convinced policy makers that a competitive organisation of the energy markets was not only feasible but, for reasons of efficiency, desirable [1]. In addition, another important motivation for promoting competition through the liberalisation of energy markets was the intention of the European Commission to create a single energy market across Europe [2].

The liberalisation of the German energy market started in 1998 with the implementation of the first liberalisation directive adopted by the EU in 1996. Until this point the energy sector was regarded as a natural monopoly, where competition would lead to inefficiency and the supply of electricity to the market was controlled by regional monopolies. These were organised as vertically integrated utilities that were responsible for generation, transmission and distribution of electricity (see Figure 1.1). The push towards liberalisation was driven in part by the belief that the concept of the natural monopoly was only applicable to the transmission and distribution part of the electricity value chain and that competition among generators and retailers of electricity would result in gains in efficiency and lower prices for end-consumers.

Since then, numerous other legislative initiatives have been taken, including the *Second Energy Package* in 2003 and the *Third Energy Package* in 2009 amongst others. Two important initiatives are the *Energy Action Plan* from March 2007 which identifies sustainability, security of supply and competitiveness as three major challenges and places them at the centre of European energy policy, and the *Climate and Energy Package 2020* from January 2008 which set out three important targets for EU policy making [3].

- To reduce EU greenhouse gas emissions by 20% below the 1990 levels
- To increase the share from renewables in EU energy consumption to 20%
- To improve energy efficiency by 20% relative to 2007 projections about energy consumption in 2020.

Further to this, the *Energy Union Strategy*, published in February 2015, set out five closely related and mutually reinforcing dimensions aimed at building an energy union that gives EU consumers secure, sustainable, competitive and affordable energy [4][5]. These are:

- Improved energy security, solidarity and trust.

- A fully integrated internal energy market enabling the free flow of energy through the EU.
- Improved energy efficiency contributing to moderation of demand.
- Climate action and decarbonisation of the economy.
- Research, innovation and competitiveness in the energy sector.

Also in 2015, as part of the *Paris Climate Agreement* the EU pledged to move further ahead and achieve greenhouse gas emission reductions of at least 40% by 2030. In 2016 a set of ambitious new rules called the *Clean Energy for all Europeans Package* was proposed by the EC. This package addressed all five dimensions of the Energy Union Strategy and it's implementation was concluded in May 2019 [6].

More recently, the President of the European Commission, Ursula von der Leyen, proposed the *Sustainable Europe Investment Plan* also known as the *European Green Deal* during her candidacy for President of EC in 2019, in which she pledged a trillion Euro of investment over the next decade in green and sustainable financing [7]. This was then confirmed in the resolution of January 2020 [8] and at the most recent EC summit in December 2020 the EC endorsed a binding EU target of a net domestic reduction of at least 55% in greenhouse gas emissions by 2030 compared to 1990 in order to meet the objective of a climate-neutral EU by 2050[9].

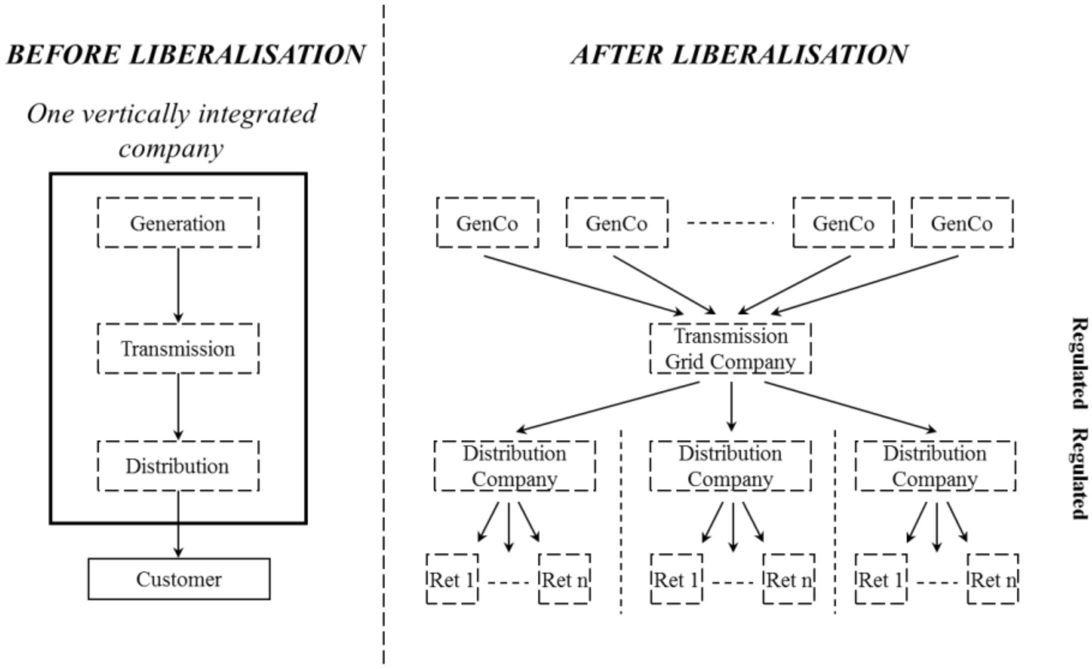


Figure 1.1: The structure of the energy market before and after liberalisation[3].

In addition to objectives set at a European level, an important factor for driving change in the German energy sector is the German *Energiewende*, which translates as *Energy Transition.* This term was first introduced in 1980 and refers to the ongoing process in Germany of transitioning to a carbon-neutral, nuclear-free economy, and to ensure that the future is secure, environmentally-friendly and economically successful [10]. An important aspect of the energy transition is the *Renewable Energy Act*, which was originally introduced in the year 2000 to encourage the generation of renewable electricity and has since been modified several times with the latest modification being implemented in January 2021. In addition to this, Germany's first *Climate Action Law* was introduced in December 2019 which for the first time enshrined a commitment to reduce greenhouse gas emissions into law. This was accompanied by the *Climate Action Programme 2030* which stipulates measures to assist in compliance with the Climate Action Law [11]. The current targets of the Energiewende as defined by the Federal Ministry for Economic Affairs and Energy are [10]:

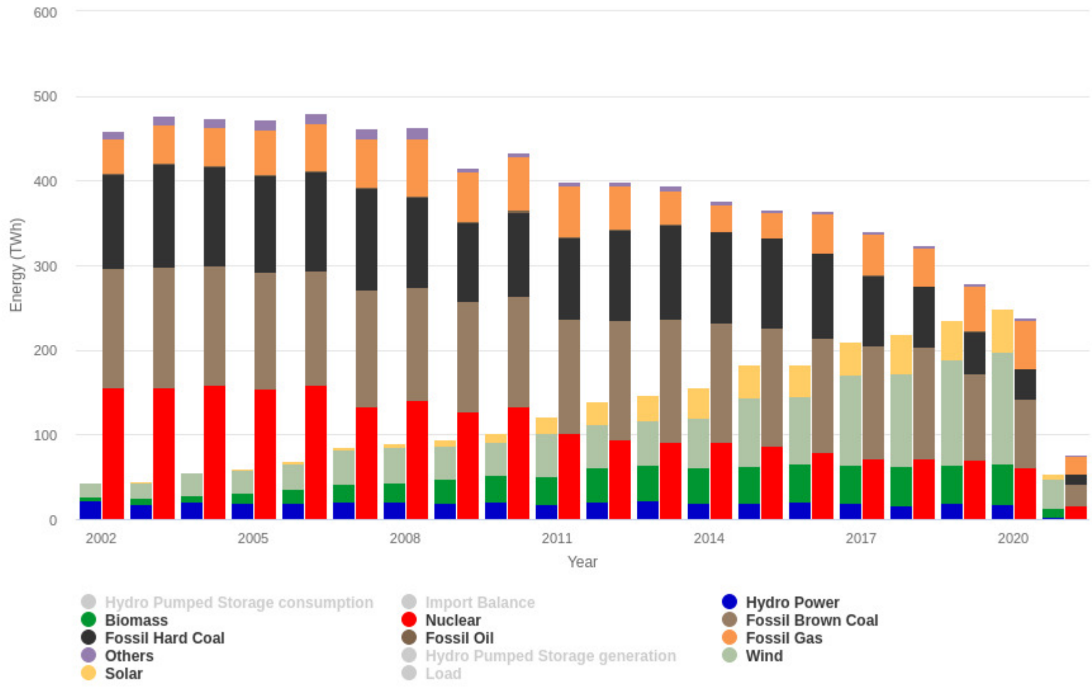
- An increase in the proportion of electricity coming from renewable sources to 65% by 2030.
- The shutting down of the last remaining nuclear power plants by 2022.
- A reduction of greenhouse gas emissions to 55% below 1990 levels by 2030.
- A 50% reduction in primary energy consumption compared to 2008 levels by 2050.

While there has been success in the areas of electricity generation and consumption (in the 2010 Energy Concept, Germany aimed for renewables to account for 35% of gross electricity consumption by 2020 and overachieved this with 38% in 2018 and 44% in the first half of 2019 [12]), transport and heating (which accounts for over 50% of final energy consumption and around 40% of emissions [12]) have lagged behind and continue to be the most significant hindrance to Germany meeting it's greenhouse gas targets. What is clear is that there has been significant change in the German energy sector in the years following the liberalisation of the energy market and that this change is set to continue well into the foreseeable future. Figure 1.2 clearly shows the change in electricity generation over the last 20 years and Figure 1.3 shows how this change is due to continue in the areas of personal transportation and home heating until the year 2050.

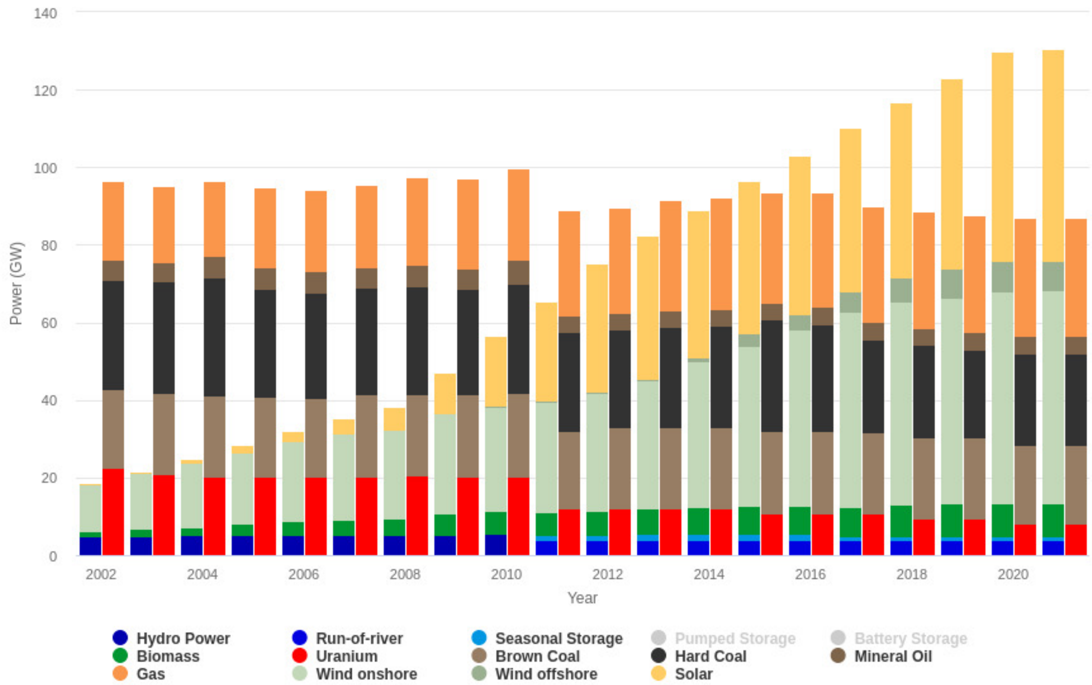
An additional component of the Energiewende has been the transition from a centralised form of energy generation and distribution to a more distributed system. This has been greatly assisted by the popularity of private home solar installations and by the end of 2020 there was a total of 54 GW of installed photovoltaic power, accounting for 9.3% of the total electricity consumption, distributed across 2 million solar installations [13].

The liberalisation of the sector, coupled with policy and regulatory reforms on both a European and a national level, all reinforced by the introduction of new technologies, has created new opportunities for existing and emerging business models in areas such as electromobility, photovoltaic electricity production and sector coupling. Furthermore the continued expansion, diversification and decentralisation of the energy sector has led to increased complexity within the sector. In their work from 2019, which has heavily influenced this thesis, Giehl et al. made the point that the classic structures of the energy industry are subject to massive changes. The need for decarbonisation has caused a shift to renewable energy production which in turn has promoted the decentralisation of the energy system and digitalisation has lead to increased interconnectivity between different elements of the energy system. All of this leads to the conclusion that reference to value chains within the energy sector is becoming increasingly obsolete as value chains become to a much greater extent value networks [14].

This study aims to investigate how the representation of business fields within the German energy sector has changed in the time period from 2010 to 2019 by looking at the language used by companies operating within this sector on their websites and checking to what extent different business fields have come more into, or fallen out of common discourse.

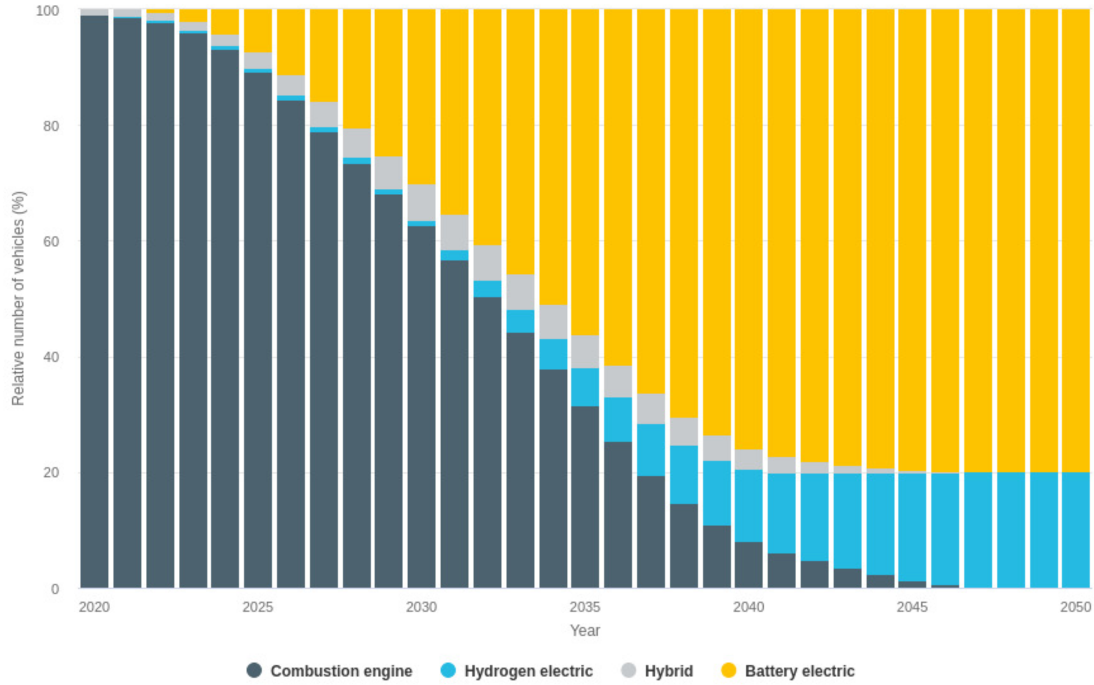


(a) Annual net electricity generation in Germany

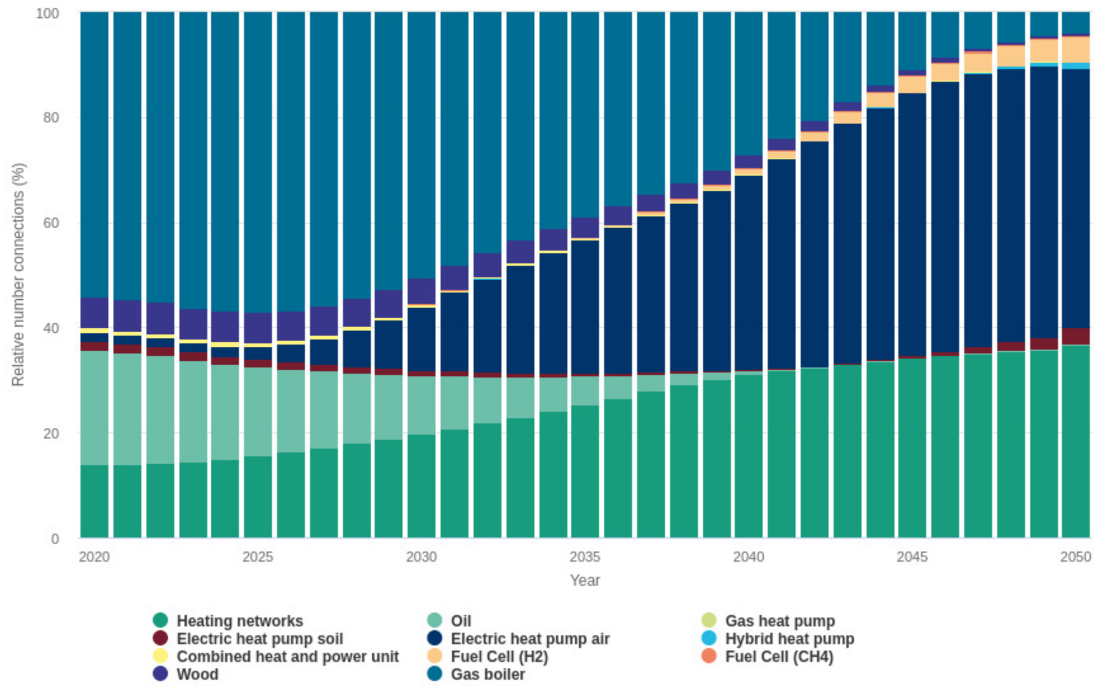


(b) Net installed electricity generation capacity in Germany

Figure 1.2: The development of electricity generation in Germany over the last 20 years[15].



(a) Drive technologies in passenger car traffic



(b) Heating technologies in the heating of buildings

Figure 1.3: The planned development of the building heating and passenger transportation sectors until 2050[15].

1.2 Objective

The aim of this research is to assess changes in the representation of business fields of the German energy sector by companies operating within it. With this main aim in mind, the key questions that this study will attempt to address are:

- To what extent are business fields found in the German energy sector represented on company websites?
- How has this level of representation changed from 2010 to 2019?
- How have the mean levels of representation changed on a federal state level?
- How have the mean levels of representation changed between the sub sections of the section "Electricity, Gas, Steam and Air Conditioning Supply" of the NACE rev.2 codes?
- Which of the business fields are most commonly represented together?

1.3 Scope

To implement the objectives of this thesis the text contained on the websites of companies whose main activity is classified within the section "Electricity, Gas, Steam and Air Conditioning Supply" of the standard industry classification system used in the EU, the NACE rev.2 coding system, in the decade from 2010 to 2019 will be examined. A thesaurus based approach to text categorisation will be employed to categorise the text data from company websites according to the extent that individual business fields are represented within the data. The various business fields will then be ranked according to the levels of representation and the changing rankings of the business fields over the considered time period will then be examined for Germany as a whole, for each federal state of Germany and for each of the sub sections of the NACE rev.2 codes that are to be found in the data set used for this thesis. The extent to which business fields are represented together on company websites will also be looked at. While the changing levels of representation of the various business fields will be considered, the reasons for these changes go above and beyond the limits of the scope of this thesis and will not be considered.

1.4 Outline

This thesis consists of the following chapters:

Chapter 2, Fundamentals and Related Work, introduces and gives a short summary of the most relevant concepts used in this thesis and some of the other works that they have featured in.

Chapter 3, Implementation, describes the steps involved in the implementation of this thesis, including data acquisition and processing, the creation of a business model thesaurus and the text categorisation process.

Chapter 4, Evaluation, presents the results obtained in graphical form and provides some observations of the results.

Chapter 5, Conclusion, summarises the thesis and gives an outlook about possible future work.

2 Fundamentals and Related Work

This chapter provides an introduction to the relevant concepts found in this thesis. To start with, an overview of the definitions of the various business model classes existing within the German energy sector is laid out. The field of Knowledge Discovery in Databases is then introduced with some emphasis on text mining, thesaurus based categorisation and a brief introduction to the field of natural language processing.

2.1 Business Model Classes

The business model classes used in this study were defined by Giehl et al. In their study, 'Survey and classification of business models for the energy transformation', they note that although there are various studies referring to individual, specific business models, technologies and use cases within the energy system, there is no exhaustive overview of currently existing energy business models [14]. In order to address this gap in the current research they developed a 'business model framework for the energy industry' based on literature analysis which used the following components to characterise individual business models.

- Value proposition - The value generated by a company for its clients.
- Customer segment - Customer groups addressed by the value proposition.
- Revenue model - The generation of cash flows from customer relationships.
- Utilised technology - The main technologies that support the competitive advantage of the company.
- Required and offered data - Monetary and non-monetary valued data links.
- Influencing factors - Energy specific technological, political and market aspects.
- Level in the energy value chain - Allocation of the business model within the classical value chain.
- Function in the value creation network - Common characteristics of companies based on the business model handbook of Osterwalder and Pigneur [16].
- Required partners - The extent of dependence on the business models of others.

The result of this analysis was to identify a total of 638 business models within the energy industry. These were then condensed into 69 business model prototypes which in turn were used to characterise 17 business model classes. It is these business model classes that form the point of reference for the analysis of the German energy sector in this study. The following subsections provide a brief overview of these business model classes and the business model prototypes contained within them.

2.1.1 Administrative Services

The class *Administrative Services* is comprised of business models that enable certain tasks and services to be carried out by third parties, thus allowing their clients to concentrate on their core activities. The business model prototypes that make up this class are *Billing Services*, whereby a billing service provider assumes responsibility for billing and invoicing for energy producers and suppliers; *Administrative Services*, that represents companies that provide a billing system for customer management and data administration; and *Distribution Services*, which incorporates the business models of companies that offer services such as customer relationship and cash flow management.

2.1.2 Analytics

The preparation, evaluation and interpretation of large volumes of data is generally what is implied by the business class *Analytics*. More specifically the class is comprised of 4 prototypes. *Data Trading*, which includes business models based on the sale of customer data. *Generation Analysis* , which analyses generation data for the purpose of automated optimisation such as maintenance optimisation or early error detection. Business models of the prototype *Systems Analysis* offer machine learning based services that combine and analyse data from various sources in order to assist with predictive maintenance, system optimisation or the grid integration of renewable energies, and companies of the prototype *Consumption Analysis* offer software based tools or services for the analysis of energy consumption with the aim of optimising efficiency and reducing environmental impacts.

2.1.3 Consumer Services

The class *Consumer Services* covers a diverse field of customer focused services that utilise a wide range of technologies from digital components to analogue measurement technologies. The 4 prototypes associated with this class are: *Energy Consulting*, which incorporates consulting based business models orientated towards identifying measures and developing energy solutions for consumption optimisation, general system optimisation and cost reduction for industrial customers and customers involved in trade, commerce and the service industry; *Mobility Services*, which covers business models dealing with a holistic mobility management service where new market entry points are possible through combinations of public transport and private transport; *Procurement*, relates to business models whereby companies procure gas, electricity and other energy sources for third parties and additionally, in the case of large customers, assume responsibility for risk and portfolio management; and *Testing Services*, is characterised by business models relating to energy surveying of buildings and installations for the purposes of improving the transparency of energy consumption, operational reliability and, where relevant, providing energy certification.

2.1.4 Conventional Production

The business model class *Conventional Production* is divided into 2 prototypes. Included in the prototype *Conventional Production* are business models of independent producers of heat and electricity who utilise conventional technologies as their means of production and who may additionally provide control energy for the purpose of maintaining grid frequency stability. The prototype *Conventional Energy Supplier* relates to businesses that promise stable and secure delivery of large quantities of energy such as electricity, gas and heat. In addition, some energy suppliers, most notably 'Stadtwerke', assume responsibility for other conventional municipalities such as the provision of water and local public transportation.

2.1.5 Engineering & Construction

The 2 prototypes that make up the class *Engineering & Construction* are concerned with the provision of technology for the energy sector. The first of these, *Plant Manufacturer*, focuses primarily on the development and production of technologies for the energy sector for not only large industrial customers but also smaller businesses and domestic application. The prototype *Systems Technology Manufacturer* focuses solely on the manufacture of specialised components for energy facilities rather than complete systems.

2.1.6 Energy Services

The business model class *Energy Services* comprises of 4 prototypes that, while focusing on ensuring the technical operation of facilities located in the vicinity of the consumers, are regarded as service providers for the consumers. The prototype *Energy Contracting* contains business models that are based on providing customers with energy in the form required by them such as electricity, gas, heat, light or compressed air. The prototype *Power for Tenants*, from the German 'Mieterstrom', is comprised of business models that involve tenants consuming electricity and/or heat that is generated in the immediate vicinity and that isn't transmitted through conventional infrastructure such as the transmission grid. The prototypes *Technical Operations Management* and *Technical Operations Management PV* both focus on business models where the business, as a service for the customer, assumes the complete responsibility for operation and upkeep of a facility, including necessary maintenance, optimisation, certification etc. The difference between the two prototypes being that the latter focuses solely on one technology and is directed primarily at household customers.

2.1.7 Flexibility Options

Encompassed within the business model class of *Flexibility Options* are a diverse range of business models associated with the facilitation of flexibility within the electricity grid, allowing for the adjustment of generation and consumption in accordance with demand. This is realised by the utilisation of a broad range of technologies including decentralised measuring and control technologies, batteries and diverse generation and consumption capacities. This class is characterised by 5 prototypes: *Demand Side Management (DSM)*, which focuses primarily on consumers with large capacities but also on households with flexible consumption capacities; *DSM Ancillary Services*, focuses on business models based on providing control power through demand side management measures by large consumers; The prototype *Power-to-Mobility DSM & Ancillary Services* supplements the preceding prototype by taking into account business models that offer grid load stability and a reduction of the need for dispatch measures by offering specific generation or consumption profiles in addition to classic products of the control energy market; *Storage DSM* focuses on energy storage based services such as load profile smoothing or load profile optimisation that are offered, primarily by large consumers but also by prosumers, in order to reduce costs; and *Storage Ancillary Services* covers business models where energy storage services are offered to grid operators for the purpose of grid stability.

2.1.8 Infrastructure Operation

The class *Infrastructure Operation* contains business models that deal with different areas of the infrastructure operation of the energy system such as storage operators and grid operators. The 4 prototypes contained within this class are: *Asset Leasing*, a prototype that includes business models where the grid owner makes the grid infrastructure available to an operator in return for lease fees on the basis of long-term contracts; *Microgrid Operation* includes business models that guarantee locally generated energy that is independent of the conventional grid; *Grid Operation* incorporates business models dealing with the transportation and distribution of energy via the respective grid; and the prototype *Storage Operation* corresponds to business models of companies that sell energy storage capacity.

2.1.9 Measuring

The class *Measuring* consists of 3 prototypes linked directly to the field of metrology with an emphasise on decentralised metering technologies. The first of these prototypes, *Measuring Services*, is characterised by business models involving the collection, processing and preparation of meter (primarily smart meter) data. The prototype *Metering Point Operator* includes business models of companies that enable connection to the grid and that are involved in the administration and upkeep of installed metering technologies. With the introduction of smart technologies and the 'smart meter roll-out' the role of companies operating within this business model prototype has often expanded to include the responsibility of smart meter gateway administrator. The third prototype, *Smart Meter Services*, includes companies that assume the tasks of smart meter gateway administrators and also data collection and provision with the promise of optimising the process and thus reducing costs.

2.1.10 Platforms

Within the class *Platforms* are a further 8 business model prototypes which all share the common characteristic that they enable the networking of people and/or companies and simplify the interaction between different players in the energy industry. These prototypes are: *Exchange*, which represents a marketplace for buying and selling energy with the promise of fast and efficient transaction processing; *Crowd Storage Platform* business models allow customers to use their own self-generated electricity as a form of virtual energy storage, further integrating renewable energies and ensuring grid stability; *Information Platform* business models, which provide customers with information that promises to reduce and/or optimise costs, such as price or device comparison services; *Power-to-Mobility Charging Infrastructure Platform*, which focuses on business models offering charging points for electric vehicle owners, independent of individual providers; *Peer to Peer Platform* is characterised by business models offering a market platform for direct trading between customers, thus reducing costs by removing intermediaries; business models of the prototype *Platform for Energy Services* offer IoT platforms for the purpose of energy management and consumption optimisation. Additionally, they may provide services such as energy data management, metering or the provision of heat and/or electricity; *VPP Energy Marketing* covers business models whereby the power from distributed energy resources in the form of a virtual power plant is sold to customers; and *VPP Ancillary Services* concerns business models that market producers and consumers within a virtual power plant system as a single unit for the purpose of providing control energy.

2.1.11 Prosumer

The business model class *Prosumer* contains only one prototype and is itself thus considered to be a business model prototype. The term prosumer describes consumers who also produce that which they consume. Examples of this in the context of the energy sector are owners of combined heat and power plants and domestic photovoltaic systems. Although by its nature the business model *Prosumer* cannot be realised by a company, it is a necessary prerequisite for other companies to exist and offer their services.

2.1.12 Renewable Energies

The business model class *Renewable Energies* is comprised of 3 prototypes dealing with the supply of fuels and the generation of renewable heat and electricity. The business models of this class relate exclusively to large scale generation and exclude small consumers and producers. The prototype *Renewable Fuels* is made up of business models centred around the production and supply of renewable energy carriers. The prototype *Renewable Generation* consists of business models relating to the conversion of renewable energy sources into electricity and heat, and the prototype *Renewable Energy Supplier* is comprised of business models focusing on the supply of renewable energies.

2.1.13 Sales Methods

The class of *Sales Methods* consists of 7 further business model prototypes dealing with the different forms of trading energy or energy related products, primarily through the use of software and corresponding data platforms. These are *Consumer Sales*, which is made up of business models focused on the generation of revenue through the sale of electricity, gas and/or heat; *Energy Trading*, which represents companies that trade electricity and/or gas, either independently or for third parties; *Customer Services based on Energy Data* relates to business models based on smart home solutions that link different sectors together via data, offering for example, the integration and ease of use of home technology and improved energy efficiency and energy cost reductions; the prototype *Storage Trade* consists of business models whereby revenue is generated through the sale of electricity and gas held in storage reserves; *Ancillary Services Marketing* incorporate business models of companies that offer either their own or third party generation and/or consumption capacity on the control power market; the prototype *Marketing* relates to business models where companies guarantee market access and assume responsibility for the marketing of electricity generated by third parties; and the prototype *Distribution of related Goods* represents an addition to the basic business model of the supply of energy whereby energy related products are offered to consumers, an example of this being energy saving lighting.

2.1.14 Sector Coupling

The business models of the class *Sector Coupling* correspond to various arrangements linking the electricity, gas, heat and mobility sectors and the relative technologies and infrastructure required for their implementation. The prototype *Power-to-Gas* includes business models based on the conversion of electricity into gaseous energy carriers such as hydrogen or synthetic gases. Similarly, the business models of the prototype *Power-to-Heat* are concerned with the conversion of electricity into heat to be used in the neighbouring vicinity. The two remaining prototypes in this class, *Power-to-Mobility Power Supply* and *Power-to-Mobility Charging Infrastructure* both include business models pertaining to the use of electrical power in the transport sector with the difference being that the former focuses on the supply of electrical power and the relevant necessary technologies while the later focuses on the provision of the charging infrastructure required for the e-mobility sector.

2.1.15 Software Provider

The class *Software Provider* includes a total of 7 prototype business models that focus on providing software solutions for the energy sector. These include *Energy Efficiency Software Provider*, which includes business models that offer energy management systems for energy monitoring and improving the degree of transparency of consumption; *Network Operation Software Provider*, including business models whereby distribution grid management software is offered for the purpose of automated monitoring, control and forecasting of grid operations; *Power-to-Mobility Software Provider*, comprising of business models of companies that offer solutions for operating the charging infrastructure of the e-mobility sector; *Platform Software Provider*, which covers business models where the focus is on offering platform operators the software required to run their platforms with the promise of cost reductions through automation and increased efficiency; the prototype *PV Software Provider*, whereby intelligent control software enables providers of photovoltaic systems to offer their customers comprehensive production and consumption optimisation; business models of the prototype *Storage Software Provider*, which provide software for the operation and grid integration of energy storage systems; and the prototype *VPP Software Provider*, which is made up of business models focused on providing software for virtual power plant operators in order to automate control and optimisation of the virtual power plant.

2.1.16 Technical Services

The business model class *Technical Services* is divided into 6 business model prototypes that focus, on one hand, on the implementation of decentralised measurement and control technology and artificial intelligence solutions and, on the other hand, on the provision of large scale generation capacities. The first of these prototypes, *Carbon Capture and Storage (CCS)*, is based on the capturing and storage of carbon-dioxide emissions from power plants and industrial facilities. The prototype *Energy Management System* covers business models through which systems, both software and hardware based, for energy management and monitoring are offered. Additionally customers are offered extensive advice, and assistance with development of measures. Load management measures may also be offered. The business model prototypes *Renewable Project Planning* and *Power Plant & Grid Project Planning* are similar in that they both cover business models dealing with the planning and implementation process of construction, repowering or dismantling of large scale facilities. The difference between the two prototypes being that the former focuses on renewable power generation plants while the later is focused on conventional power plants or grid expansion. The business models of the prototype *Modernisation* are focused exclusively on the upgrading and subsequent sale of existing facilities and business models of the prototype *Maintenance & Retrofitting* offer the service of plant optimisation in combination with a maintenance strategy.

2.1.17 Technology Sales

The two business model prototypes of the class *Technology Sales* are comprised of business models based around the development of customised systems using components from other suppliers. The first of these, *System Distribution*, represents business models through which complete system solutions are developed and distributed while the other prototype, *Technology Distribution*, represents business models through which solutions for electricity and heat generation and storage are offered to energy producers, manufacturing companies and households. Other aspects such as financing, planning, installation or maintenance may also be offered.

The following section provides an introduction to the field of Knowledge Discovery in Databases with particular emphasis on text mining and thesaurus based categorisation. In addition a brief introduction to some relevant concepts from the field of natural language processing is provided.

2.2 Knowledge Acquisition from Text Data

The storing of information is nothing new. In it's most basic form human speech stores abstract information in the form of sounds to be replicated in order to share this information. The advent of writing allowed information to be stored for longer periods of time with greater accuracy and thus promoted the development and expansion of cultures that had access to this form of information storage. The development of electronic computational devices in the period following the second world war allowed for the storage of ever larger data sets onto magnetic tapes and with the emergence of personal computers and the internet during the 80s and 90s the world saw an explosion in the amount and complexity of data which could be stored and easily accessed [17]. Contained within large databases are often useful lessons to be learned or patterns to be discovered but often the size of databases makes a manual probing of data sets slow and expensive and in many cases, as data volumes continue to grow, completely impractical. These challenges led to the implementation of computational and statistical models in order to extract useful information from large data sets and the eventual emergence of the field of *Knowledge Discovery in Databases*, KDD, which is defined as "the nontrivial process of identifying valid, novel, potentially useful, and ultimately understandable patterns in data" where the term *nontrivial* means that "some search or inference is involved; that is, it is not a straightforward computation of predefined quantities like computing the average value of a set of numbers" [18]. An early version of the KDD process was defined by Usama Fayyad, Gregory Piatetsky-Shapiro, and Padhraic Smyth in 1996 and is designed to lead from raw data at the beginning to knowledge at the end[19]. The steps involved in the Fayyad et al. KDD process, as shown in Figure 2.1, and which may be, and are often expected to be, implemented as an iterative process, are as follows[18]:

- Selection of the data to be examined.
- Cleaning and preprocessing of the data.
- Dimensionality reduction or transformation of the data to reduce the effective number of variables to be considered.
- Application of suitable data mining methods to search for patterns of interest. These may include summarisation, clustering, classification or regression to name a few
- Interpretation and evaluation of the results.

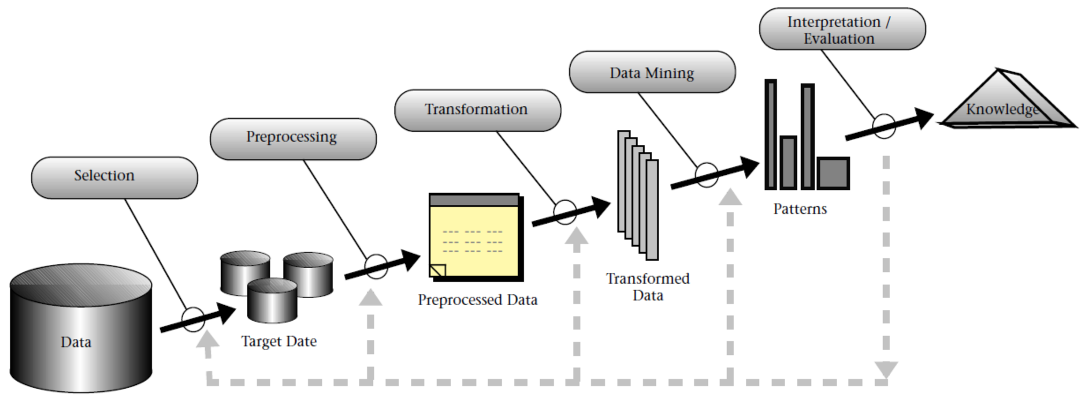


Figure 2.1: The steps involved in the KDD Process[18].

2.2.1 Text Mining

The field of text mining is a form of data mining which deals with data in the form of text. Text is the most natural way of encoding human knowledge and by far the most common type of information encountered by people. The explosive growth of online text information has provided a vast resource of information rich in semantic content and often containing valuable knowledge, information, opinions and preferences of people. This provides a great opportunity for discovering various kinds of knowledge, useful for many applications, while at the same time it is beyond the ability of any individual to obtain and maintain an overview of the data, thus creating the need for intelligent tools to assist with the retrieval and analysis of text data. An important aspect of text data, as opposed to other forms of data, is that text is generally produced by humans with the intention of being consumed by humans. This contrasts to other forms of more structured and more explicit data that tend to be generated by machines. At the current stage of technological development, humans can understand text data far better than computers can and as such, human involvement in the mining and analysing of text data remains crucial [20]. The goals aimed for by the process of KDD can be initially distinguished into two types. The first type, *verification* is a confirmatory approach and the second type, *discovery*, can be considered an exploratory approach. An exploratory approach asks the question "What does the text contain?". Systems following this type of approach autonomously find new patterns in text data and are generally implemented when the content of the text is impossible to anticipate [18][21]. A example of exploratory analysis is *Topic Modelling*, of which a currently particularly popular method is *Latent Dirichlet Allocation*, LDA. This type of analysis is a probabilistic model that assumes that given a corpus of documents, each document is a distribution over the topics and in turn every topic is a distribution over the words in the corpus [22]. This means that a given document can be represented as a mixture of hidden or latent topics contained within the document where a topic is defined by the terms associated with it [23]. A confirmatory approach asks "Does the text contain what I expect it to contain?". This type of approach is limited to verifying the user's hypothesis whereby terms that represent individual categories or topics are defined independent of and prior to any analysis [18][21]. Each document is then categorised based on predefined categories. It is this confirmatory approach that is followed in this thesis where the business model classes described in the previous section form the categories that are to be verified. A similar approach was also taken in a study by Manuel Bickel that assessed some local transition patterns in the context of the German Energy Transition [24].

Thesaurus Based Categorisation

The form of text mining applied in this thesis can be best described as thesaurus based text categorisation. Romero et al. provide an in-depth description of such *Thesauri* and their applications for text categorisation in their publication, *Thesaurus-Based Automatic Indexing* [25]. Although it is not necessary to go into great detail about all of the diverse facets of such analysis, the components most relevant for this thesis are outlined in the following paragraph.

In it's most rudimentary form, a Thesaurus is comprised of sets of terms which are relevant to a particular area of knowledge. The basic unit of a thesaurus is referred to as a *descriptor*, which is a word or phrase that identifies an important concept within that area of knowledge. The following sets represent the terms and descriptors in the thesaurus.

$$\Omega = \{\omega_1, ..., \omega_n\}$$
$$\Delta = \{\delta_1, ..., \delta_n\}$$
$$\Gamma = \{\gamma_1, ..., \gamma_n\}$$

In the categorisation process, a set of categories, $\mathcal{C} = \{c_1, ..., c_{|\mathcal{C}|}\}$ can be mapped onto a set of documents, $\mathcal{D} = \{d_1, ..., d_{|\mathcal{D}|}\}$ whereby a category can be assigned to each document in what is known as *single label categorisation*, or several categories can be assigned to a document in what is known as *multi label categorisation.* Furthermore, the categories may be ranked in order of their relevance to the document. In this scenario each category is allocated a *Categorisation Status Value*, CSV. In combination with a given threshold, τ, a category, c_i, is assigned to a document if $CSV_i \geq \tau_i$ [25].

Such thesaurus based approaches to categorisation have been used in previous studies to classify suppliers in the manufacturing industry according to their manufacturing capability [26], to develop a semantic classification model for classifying adjective-noun and verb-noun collocations in the English language [27], and to classify Mauritian owned websites into a number of broad categories relating to societal and civil areas [28].

2.2.2 Natural Language Processing

The term *natural language* refers to naturally occurring human languages such as German, Russian or Chinese, be they spoken or written. These are languages that have evolved naturally and are thus considered distinct from so-called *artificial languages*, such as Quenya, one of several Elvish languages created by the author J.R.R. Tolkien, or Esperanto, and also from *formal languages*, which have explicit and precise rules for syntax and semantics, such as programming languages, the notation used by mathematicians or the representation of chemical structure of molecules used by chemists[29]. *Natural Language Processing*, NLP, is broadly defined as "an interdisciplinary area of research aimed at making machines understand and process human languages"[30]. Natural languages and the rules that govern them are ambiguous, highly variable and subject to change. Furthermore the inclusion of elements such as sarcasm, double negation and rhetorical expression ensure that the comprehension of natural languages is a task beyond the capability of machines and indeed even for humans not always entirely straightforward[30][31]. In his book, *Mathematical Linguistics*, Andras Kornai points out the extent to which working with natural language is a difficult task.

"As we all know, dealing with natural language is hard. It is hard from the standpoint of the child, who must spend many years acquiring a language (compare this time span to that required for the acquisition of motor skills such as eating solids, walking, or swimming), it is hard for the adult language learner, it is hard for the scientist who attempts to model the relevant phenomena, and it is hard for the engineer who attempts to build systems that deal with natural language input or output. These tasks are so hard that Turing could rightly make fluent conversation in natural language the centerpiece of his test for intelligence." [32]

A few examples that highlight the nuances of natural language are that *having two weeks to go* is not the same as *having a coffee to go*, nor is *eating dinner with friends* analogous to *eating dinner with a fork* and most people will be aware that while *time flies like an arrow*, *fruit flies like a banana.*

This section will briefly explain some of the concepts associated with this field that are relevant for this thesis.

Tokenization

Tokenization is defined as the process of segmenting a text or texts into *tokens* by the white space or punctuation marks[33]. For example, the tokens comprising the sentence *Berlin is the capitol city of Germany*, would be tokenized as,

$$['Berlin', 'is', 'the', 'capitol', 'city', 'of', 'Germany']$$

which is quite straightforward. However with the introduction of punctuation this method starts to become more complicated. Consider for example the sentence *Let's go to Berlin.* In this case the tokens comprising this sentence are

$$['Let', 's', 'go', 'to', 'Berlin']$$

Here it can be noted that the value of *s* as a token is greatly diminished in comparison to it's value in the given context of *Let's*. While this method is quite effective for most European languages where the words are space delimited, some other languages, such as Chinese, have no spaces between words as understood in a European context and even in European languages the process is not without complications. The German language, for example, often makes use of compound words that are not hyphenated[34]. The longest word currently in the German dictionary is *Rinderkennzeichnungsfleischetiket-tierungsüberwachungsaufgabenübertragungsgesetz*[35] which in itself is considered to be one word but which is also made up of many individual words, prefixes and prepositions combined together.

Stemming

Stemming refers to the process of removing the endings from words and converting them to a base form known as the *stem*[30]. Stems are parts of words that carry the basic meaning.[34] For example, the words *computer*, *computerisation* and *computerise* all share the common stem of *compute*. The stem of a word may be, but is not necessarily always, a valid word in it's own right[30].

Stopword Removal

Stopwords are words that occur frequently and which are largely irrelevant to the context of the text and as such do not convey much meaning[30]. Examples of stopwords in the English language are *a*,*an*, *in*, *on*, *the* and examples in the German language are similarly, *die*, *der*, *das*, *ein*, *einem*, *im*, *in*. Stopword removal refers to the process of removing stop words from the list of tokens or stemmed words to improve efficiency[33].

N-grams

Certain phrases are made up of 2 or more words which convey a specific meaning and if used individually these words can have a different meaning and lose the inherent meaning of the compound term[30]. The terms *renewable energy* and *conventional energy* refer to different concepts, neither of which can be described by the words *renewable*, *conventional* or *energy* on their own.

Such groupings of collocating words in a text are referred to as *n-grams* where groupings of 1 word, 1-grams, are known as *Unigrams* and groupings of 2 or 3 words, 2-grams and 3-grams, are known as *Bigrams* and *Trigrams*, respectively. It is possible to extend this naming system but it is uncommon for NLP tasks to extend beyond trigrams[30].

If one is to consider the sentence *The Technische Univeristät Berlin is one of the finest universities in Berlin*, the n-grams that can be formed out of this are presented in Table 2.1

Unigrams	Bigrams	Trigrams
The	The Technische	The Technische Universität
Technische	Technische Universität	Technische Universität Berlin
Universität	Universität Berlin	Universität Berlin is
Berlin	Berlin is	Berlin is one
is	is one	is one of
one	one of	one of the
of	of the	of the finest
the	the finest	the finest universities
finest	finest universities	finest universities in
universities	universities in	universities in Berlin
in	in Berlin	
Berlin		

Table 2.1: An example of N-gram structures.

Bag-of-Words

In order for machines to be able to process text documents it is necessary to convert them into a more manageable representation. One of the most common methods is the *Bag-of-Words*, BoW, model. In this case documents are represented by *feature vectors*, where a feature is defined as an entity without internal structure and a document is represented as a sequence of features and their weights[36]. In the BoW model the structure and linear ordering of words within the context is ignored and the words that make up the document are used as the features while the the frequency of occurrence of each word in the document is the weight[36][37]. This model of vector representation is displayed below in Table 2.2. This example only takes into account unigrams but the same method can be extended to bigrams, trigrams and other n-grams to create a Bag-of-Bigrams, Bag-of-Trigrams or Bag-of-N-grams model, respectively [30].

$1^{st} Sentence$:	Time flies like an arrow.
$2^{nd} Sentence$:	Fruit flies like a banana.
Combined text:	Time flies like an arrow. Fruit flies like a banana
Bag-of-Words:	a an arrow banana like flies fruit time

	a	an	arrow	banana	like	flies	fruit	time
$1^{st} Sentence$	0	1	1	0	1	1	0	1
$2^{nd} Sentence$	1	0	0	1	1	1	1	0
Combined text	1	1	1	1	2	2	1	1

Table 2.2: The Bag-of-Words Vector Representation.

The next chapter describes the steps involved in the implementation of this thesis.

3 Implementation

This chapter describes the process followed in the completion of this thesis. Some information about the tools that were used is provided, followed by a detailed account of the various steps taken in the implementation process. This starts by providing information about the data used in this thesis and how it was acquired and processed, explaining also the sources of the data. Following on from this the process of the creation of the thesaurus developed for use in this work is outlined in full. The chapter then concludes with an account of the process of categorising the text data based on the business model classes.

3.1 Implementation Environment

This principle instruments that were used in the implementation of this thesis was a common desktop computer and the Python programming language. The specifications of the computer are presented in Table 3.1 and the most relevant Python libraries which were used were:

- pandas: An open source data analysis and manipulation tool [38][39].
- NLTK: *Natural Language Toolkit* is an open source platform for building Python programs to work with human language data[40].
- BeautifulSoup: A Python library for pulling data out of HTML and XML files[41].

	Computer Specifications
Operating System	Linux Mint 19.3 Tricia
Processor	Intel Core i7-4790K CPU @ 4.00GHz
System Memory	4 × 8GiB DIMM DDR3 Synchronous 1600 MHz

Table 3.1: The specifications of the computer used in the implementation of this thesis.

In addition, the open-source network visualisation program, *Gephi* [42], was used in the preparation of the network graphs in Figure 3.5 and Figure .30.

3.2 Text Data Retrieval and Preprocessing

3.2.1 Data Platform (Orbis)

The primary source of data used in this study was the *ORBIS* database. This is a business database run by Bureau van Dyke, a Moody's Analytics company. According to the company website, the database has information on more than 400 million companies worldwide that is collected and standardised from over 170 different sources [43]. The ORBIS database allows for the filtering of companies by the "Statistical Classification of Economic Activities in the European Community" (also known as *NACE rev.2*[1]) codes, which is the industry standard classification system used in the European Union [45]. As this study focuses on companies operating within the energy sector, only information on companies whose main activity was classified within "Section D - Electricity, Gas, Steam and Air Conditioning Supply" of the NACE rev.2 codes was selected for download and subsequent investigation. The amount of information available for each company varied depending on various factors such as the size of the company or the amount of revenue generated and was, amongst often much more information, comprised of:

- Basic data, such as geographical location, web addresses and the date of incorporation of each company.
- Financial data and number of employees.
- The field of business as defined by various bodies e.g. NACE rev.2, NAICS.
- Information about the company shareholders and corporate group where applicable.

In total, over 36000 companies in Germany were classified within Section D of the NACE codes. One possible reason for the amount of companies registered in this class is the fact that individual wind turbines are often registered as individual entities [46]. Of these companies from the ORBIS database, 12501 of them had a URL attributed to them of which 5604 of these URLs were unique, as some of the companies were attributed to the same URL as they were subsidiaries of some larger entity. For this study only companies that were connected with a URL were considered for further investigation. 9066 of these 12501 companies also had an address associated with them and the distribution of these companies within Germany can be seen in Figure 3.1. In the ORBIS database a company is typically assigned a single primary NACE code and one or more secondary NACE codes. In total there were 11 different NACE codes that were registered by the companies in this study as being their primary activity. The majority of companies were assigned the NACE code *3511-Production of electricity* with this being the case for over 60% of the companies, as can be seen in Table 3.2. The astute observer may notice that the number of primary codes adds up to a total of 12549 codes from a total of 12501 companies. The reason for this is that in a few cases some companies had more than one primary code assigned to them. Of these 12501 companies, a date of the company's incorporation was provided for 10186 of them as is displayed in Figure 3.2. Although the oldest company in the study had registered it's date of incorporation as being the year 1599, the overwhelming majority were incorporated in the time period starting in 1990 with 9057 of them being incorporated since the energy market liberalisation.

[1] NACE is an acronym of „Nomenclature statistique des activités économiques dans la Communauté européenne".[44]

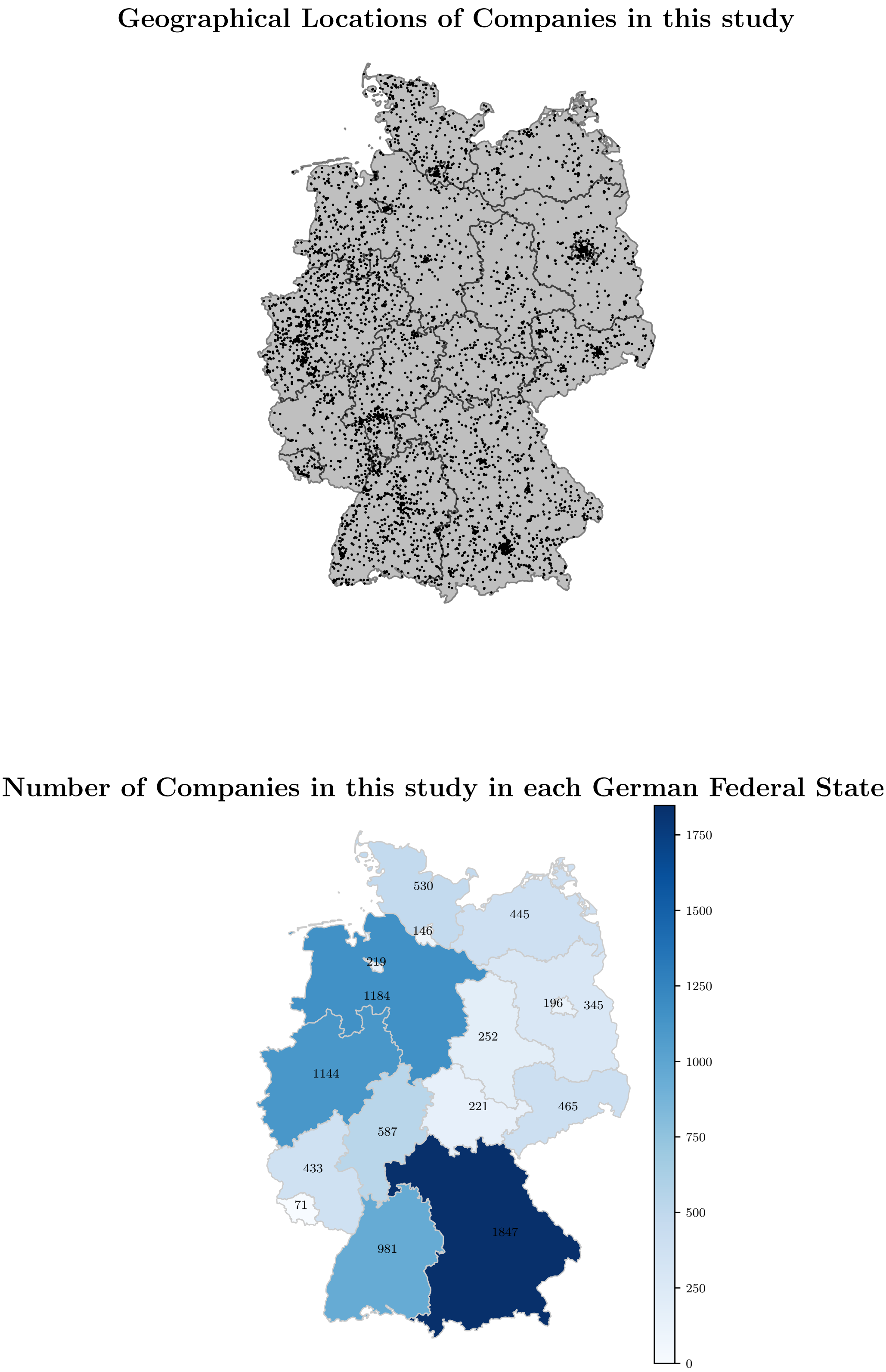


Figure 3.1: The geographical locations of the companies included in this study.

Primary NACE rev.2 Code	Number of Companies	Percent of Total (%)
3511-Production of electricity	7848	62.54
3500-Electricity, gas, steam and air conditioning supply	1010	8.05
3513-Distribution of electricity	944	7.52
3530-Steam and air conditioning supply	803	6.40
3521-Manufacture of gas	709	5.65
3510-Electric power generation, transmission and distribution	374	2.98
3514-Trade of electricity	256	2.04
3512-Transmission of electricity	249	1.98
3520-Manufacture of gas; distribution of gaseous fuels through mains	172	1.37
3522-Distribution of gaseous fuels through mains	135	1.08
3523-Trade of gas through mains	49	0.39

Table 3.2: The primary NACE rev.2 codes of the companies in this study.

3.2.2 Text Data from the Wayback Machine Archive

Retrieval of the Text Data

The source of the data used for the text analysis was the Wayback Machine, described in section 3.2.2, and the websites from which historical snapshots were to be gathered were obtained from the ORBIS databank as outlined in the previous subsection. The Wayback Machine provides various APIs for developers to use in order to interact with the archive. A previously established project, the *wayback-machine-downloader*, had incorporated one of these APIs into a tool written in the Ruby programming language, dedicated to extracting archives linked to particular websites [47] and it was this tool that was used to obtain the data from the archive. Due to the relatively large number of websites to be studied it was necessary to automate the function of this tool. For this purpose a "decorator", which extends the behaviour of the tool, without permanently modifying it's essential function, was written in the Python programming language that could automate the process for a given list of URLs. This was then used to download all the text data from the archive for each website for the time period between, and including, the years 2010 and 2019. Table 3.3 shows some statistical information relating to the number of snapshots taken of each website which is an indication of how often a website was crawled by a web crawler affiliated with the Wayback Machine. Here it can be seen that not every website had information available for every year of the study and while most of the websites were not visited more than 100 times per year, a few of the more prominent websites were visited many thousand times per year.

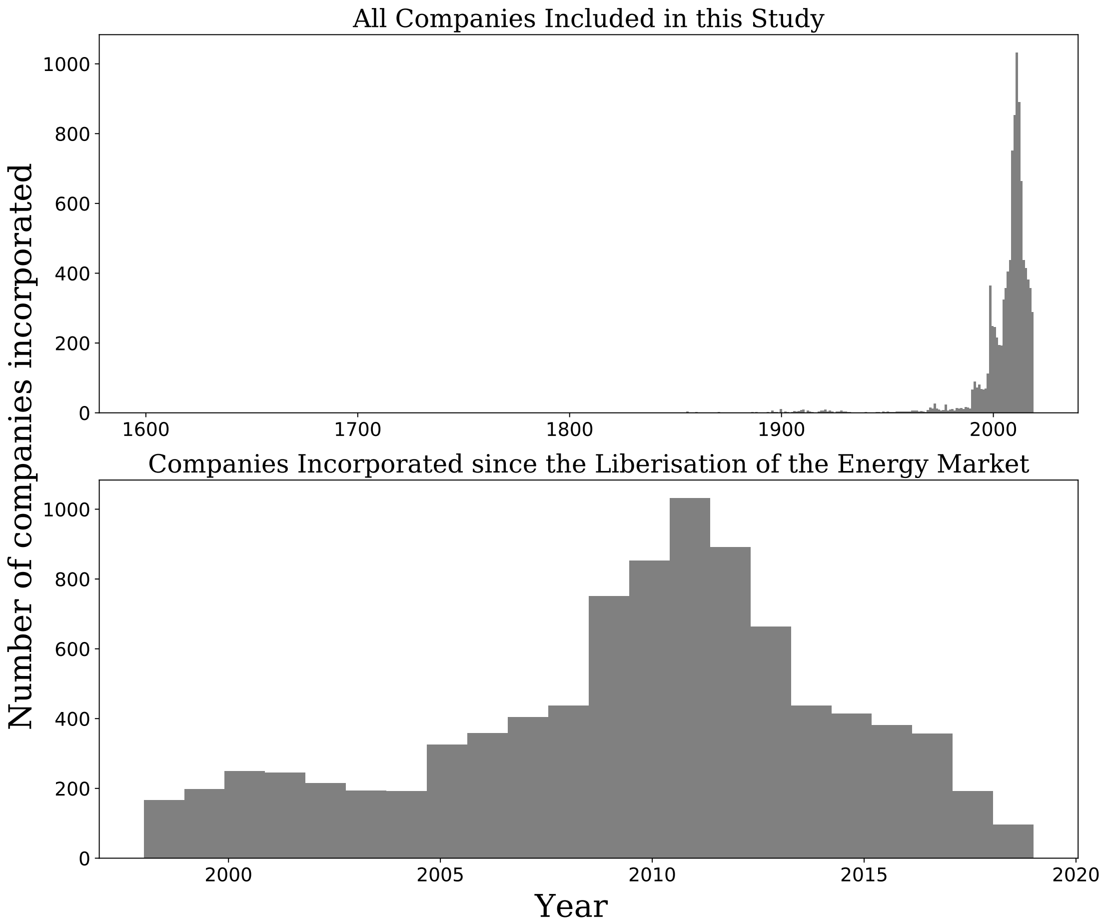


Figure 3.2: The dates of incorporation of the companies included in this study.

year	Number of Websites	mean	std	min	25%	50%	75%	max
2010	2092	164	757	1	3	18	74	18535
2011	2658	141	559	1	2	15	74	12147
2012	2684	156	597	1	3	20	82	10659
2013	3880	118	477	1	3	16	60	11150
2014	3643	106	568	1	3	13	52	18733
2015	3638	123	557	1	6	22	76	21576
2016	4084	183	693	1	10	37	129	27316
2017	3861	108	502	1	4	17	66	20613
2018	4060	72	231	1	4	12	46	4470
2019	3353	49	153	1	2	8	34	2423

Table 3.3: The number of snapshots per website.

The Wayback Machine

The *Internet Archive* is a non profit digital archive of internet sites and other cultural artefacts in digital form that has been archiving content since 1996 [48]. The aim of the Internet Archive is to provide "universal access to all knowledge" and the project was started out of the concern that in contrast to conventional mediums of information, such as newspapers which are routinely archived, much of the content online was not being stored for future reference. This concern was relevant also for academic studies as web citations became the norm in scholarly literature and it was noted that often online citations used as references in scholarly journals would disappear, thus undermining the purpose of and the academic value of referencing previous works [49].

The *Wayback Machine* is a service provided by the Internet Archive that allows archives of web pages to be searched and accessed. It was initially launched in 2001 with an archive amounting to over 10 billion web pages and currently has over 547 billion web pages included within the archive, making it the largest publicly accessible archive in the world [48][50]. The archive of web pages is compiled through the use of *web crawlers* run by various contributing partners and the archive is comprised of "many different collections driven by many organisations that have different approaches to crawling" [51]. Such web crawlers "crawl" a list of websites included in a "crawl list" and make "snapshots" of the web pages that make up these websites. In essence, they visit the identified URLs and store a digital image of the information included at the URL at the moment in time of the snapshot being taken. This may include various data formats such as PDF, mp3 or HTML code. The principle contributor to the archive has been the *Amazon* owned, web traffic analysis company, *Alexa Internet*, which has been a major source of the archive's crawl data since 1996 and which was founded around the same time as the Internet Archive by the same person, Brewster Kahle [51][52][53]. Since 2010 another prominent source has been the Internet Archive's "Worldwide Web Crawls". These crawls, run by the Internet Archive, used initially as their starting point, crawl lists which were based on the "Alexa" 1 million top ranking websites and then crawled these web pages and followed any links on these pages in order to find more information to be crawled [51]. This method of following links ensures that a comprehensive collection of all of the linked information on the web gets crawled. Additionally, individuals may flag certain web pages for crawling by the Archive. This approach to web crawling employed by the Internet Archive ensures that web pages that are generally of greater interest i.e. web pages that have more links leading to them, are crawled with a higher rate of frequency while pages that are of lesser interest get crawled less frequently. The crawls are limited to publicly available information and exclude any content providers who choose to be excluded through the use of so-called, "robots.txt" directives [54]. Some further limitations are that the crawler follows only a predetermined number of links based on a preset depth limit [55] and that the crawler cannot completely archive web pages that render anything other than standard HTML. For example, if the crawler encounters web pages that contain features such as Flash or forms written in JavaScript, which require interaction with the originating host, then much, or all, of the information on the web page will not be retrievable [54].

An important role played by the Wayback Machine for many researchers has surely been in the recovery of information from URLs that no longer exist [56]. More relevant for this study however is the possibility of using the web archive of the Wayback Machine to examine the change of particular websites over time as the information provided on a company's website can be a valuable indicator of the information that they want to communicate to the outside world and how they may wish to be seen by their customers and potential customers. A study from 2007 [57] initially validated the use of the Wayback Machine for studying website evolution over time and more recent studies have used the Wayback Machine to track website content over time in order to examine the market orientation practices of nonprofit organisations [58], to explore the correlation between dynamic capabilities and agility of small firms and the changing content on their websites [59] and to investigate the design developments of websites [60].

Preprocessing the Text Data

The archives downloaded from the Wayback Machine required some processing before they could be fit for analysis. The data downloaded was in the form of individual files with a timestamp relating to the date on which the snapshot was taken. Each file was stored in a folder with a name corresponding to the timestamp of the file and often stored in sub-folders corresponding to the particular web page within the website that was referenced by the file. In total there were more than 5 million files that, as a result of the inefficient file management structure, amounted to around 400GB of information. The first step in processing the data and reducing the complexity was to arrange all of the snapshots according to their timestamps into folders representing each month for which snapshots were available. During this process only HTML and PHP files were retained. After the process of reorganising the files, duplicate files, which were a result of the same web page being crawled more than once in a given month, in each monthly folder were removed.

The next stage of the processing involved parsing all of the HTML and PHP files to extract the text from them and concentrate it in a less dispersed form, thus further reducing the complexity and increasing the manageability of the data. Initial attempts to parse the files revealed that retrieving text clean enough to apply computational Topic Modelling methods was unfeasible. The parsed text contained a lot of residual HTML code that wasn't filtered out and also lots of Unicode characters, for example $\backslash xa0$, $\backslash n$ or $\backslash t$ all of which represent a blank space of one form or another. In addition, the text often contained a mixture of various languages beside German that couldn't be filtered out without losing a lot of the German text as well. As a result the data contained too much noise to adequately apply conventional computational methods. It was at this point that it was decided to focus on a confirmatory approach to the text analysis, rather than an exploratory approach, as described in section 2.2.1. Nonetheless it remained pertinent to clean the parsed text data. To this end the Unicode characters were all replaced with a blank space and any strings, "words", that were longer than 50 characters (a quick initial filter of the data revealed that very few words of any significant relevance contained more than 50 characters whereas long strings of condensed HTML code could often exceed this value) or shorter than 3 characters were discarded. Similarly, any strings that contained numerical digits were also discarded. In order to standardise the remaining text, all characters were converted to lowercase and all German specific characters were converted to their ASCII equivalent, for example *ä*, *ö* and *ü* were converted to *ae*, *oe* and *ue*, respectively, and *ß* was converted to *ss*. The density of the data was further reduced by removing German and English stopwords, which were bolstered by adding a comprehensive list of German place names to the stopwords, and the removal of any words that contained characters not adhering to the ASCII standard removed a lot of foreign language text, condensing the data yet further still. The applied stopwords were from the NLTK corpus.

In the final stage of the preprocessing the cleaned text data was organised into *document matrices*. For each matrix the columns corresponded to each year which is examined in this study and the rows corresponded to each website included in the study, with each matrix being made up of 10 websites for the purpose of keeping the individual file size manageable. Each cell is then an individual document comprising of the entire text data for a particular website for a given year. The general form of each matrix can be seen in Table 3.4. These documents were formed by combining the individual texts that had previously been organised in accordance with the month that they corresponded to, and subsequently removing any duplicate texts so that each individual text appears only once for a given year. Finally, each document matrix was used to create corresponding bigram and trigram matrices. After preprocessing, the file system space occupied by the combined document matrices totalled 22.8GB and the space occupied by the bigrams and trigrams was 45.5GB and 68.3GB, respectively. Table 3.5 shows some statistical information relating to the number of words in the text data for each website per year. Here it can be noticed that after the cleaning process there was information available for less websites than there were originally snapshots from. This is largely a result of no information remaining on certain websites after the cleaning process. The steps involved in the preprocessing of the text data are displayed in Figure 3.3.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
$1^{st}Website$	Text	Text	Text	Text	Text	Text	Text	Text	Text	Text
$2^{nd}Website$	Text	Text	Text	Text	Text	Text	Text	Text	Text	Text
$3^{rd}Website$	Text	Text	Text	Text	Text	Text	Text	Text	Text	Text

Table 3.4: An example layout of the document matrix.

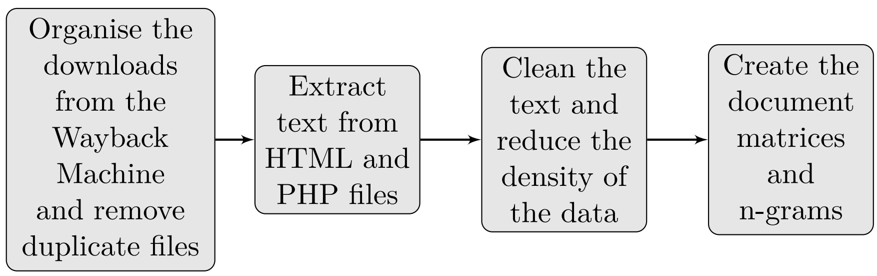


Figure 3.3: The steps involved in preprocessing the text data.

year	Number of Websites	mean	std	min	25%	50%	75%	max
2010	2039	72624	390499	1	1684	6946	30547	12335943
2011	2325	64298	306917	1	1780	7656	31819	7491513
2012	2440	69810	328303	2	1975	7820	29286	6929521
2013	3669	48804	268989	1	1274	4692	19773	7086547
2014	3465	48969	319588	2	1154	4809	19396	12087101
2015	3502	66823	421519	1	2262	8018	27426	15735761
2016	3996	82295	510139	1	1978	7653	30658	18066385
2017	3674	84232	981133	2	1582	6440	23712	36378459
2018	3935	48573	400860	1	1174	4763	17238	17258913
2019	3135	74492	744463	7	2166	9172	32023	35221696

Table 3.5: The number of words per website.

3.3 Creation of the Business Model Thesaurus

The development of the sets of descriptors that correspond to each of the business model classes as defined by Giehl et al.[14], which made up the business model thesaurus, was a multistep process which can be seen in Figure 3.4. The steps involved in this process were for the most part conducted manually. The initial basis for the thesaurus was the work conducted by Giehl et al. Access was granted to collections of terms and phrases they had compiled during the course of their study and any of these terms and phrases that were associated with the two components of their proposed *Business Model Framework*, *value preposition* and *utilised technology* (see 2.1) were initially considered for inclusion as it was these two components that contained terminology that was most specifically related to each respective business model.

Following on from this step, each set of descriptors was extended by searching the internet for terminology commonly associated with each business model class. The sources found online were made up of around 76% websites with the remaining 24% being official publications. As not every business model class was equally represented online, it proved easier to find relevant terminology for some than for others. The number of sources used for compiling each set ranged from 7 up to 17 for a total of 202 sources for the entire thesaurus and an average of 12 sources per set (see Table 3.6). A reference to each of the sources used in the creation of the business model thesaurus can be found in Section .2 of the Annex.

The subsequent step involved obtaining synonyms for the descriptors contained in each set. For this task a Python module, *py-openthesaurus*, was used that obtains synonyms in the German language from *OpenThesaurus*, which is a free to use German synonym database[61].

After adding the synonyms, many of the descriptors contained within the business model thesaurus were stemmed. This was done for two reasons, the first being that, due to the rules of Grammar in the German language, often the same word may have different endings. For example an adjective may end in *e*, *es*, *er*, *em*, or *en* depending on it's use in a sentence. For example, the term *geothermie* was reduced to a stem of *geotherm* which returned, in addition to *geothermie*, also *geothermale*, *geothermische* and *geothermischen* to name a few examples. The second reason is to enable the tagging of different but similar terms from a common stem. An example of this is the stem, *anlagenbetr*, which simultaneously registers the presence in a document, if they are indeed contained within the document, of both *anlagenbetrieb*, which refers to the operation of a plant, and *anlagenbetreiber*, which refers to the operator of a plant. Some preconfigured stemmers from the NLTK library were tested for this purpose but they generally proved to produce unsatisfactory results so this step was ultimately performed manually. The thesaurus was comprised primarily of terminology in the German language, however in some cases where the English version of a certain term was commonly found within German text then the English term was included in the thesaurus along with it's German equivalent. This included terms such as *smart meter* and *power purchase agreement*.

In a final step the stemmed business model thesaurus was used to apply the categorisation process, as described in the next section (3.4), to the document matrices to validate the categorisation process and check if it was necessary to introduce restrictions. Such restrictions were necessary to reduce noise in the data as a result of irrelevant terms being tagged by the stemmed descriptors. An example of such restrictions is that the term *plattform*, which translates into English as *platform*, and in the context of this study refers to a digital platform, tagged the terms *oelplattform* and *bohrplattform*. Both of these terms refer to offshore oil platforms and, being irrelevant in the given context, should be discarded. This final step was performed as an iterative process. The steps involved in the creation of the business model thesaurus are visualised in Figure 3.4.

After completion, the number of descriptors in each set ranged from 66 to 130 with an average of 91 descriptors per set (see Table 3.6). In total there were 1552 descriptors in the business model thesaurus of which 1320 were unique and only appeared once in the whole thesaurus. Certain terms appeared in more than one set. This occurred when a term was considered to be of particular value but also relevant to more than one business model class and reflects the fact that the business model classes themselves were not entirely distinct entities and sometimes contained overlapping areas of relevance. This is unsurprising given the intertwined nature of the modern German energy sector. One such example is the term *elektromobilitaet*, in English *electromobility*, which was considered to be relevant for both the class, *Flexibility Options*, and the class, *Sector Coupling*. Such occurrences were however kept to a minimum and care was taken to ensure that no individual term appeared in more than three sets in the thesaurus in order to maintain independence of each set from another. The network graph in Figure 3.5 shows the inter-connectivity between the sets in the thesaurus. In this graph the larger nodes represent each set where the size of the node correlates to the total number of descriptors in the set and the smaller nodes represent individual descriptors that are connected with more than one set.

Business Model Class	Number of Sources	Number of Descriptors
Administrative Services	17	74
Analytics	9	130
Consumer Services	17	93
Conventional Production	12	97
Engineering & Construction	9	70
Energy Services	16	88
Flexibility Options	14	98
Infrastructure Operation	11	83
Measuring	9	66
Platforms	15	84
Prosumer	13	90
Renewable Energies	7	108
Sales Methods	15	95
Sector Coupling	7	96
Software Provider	13	84
Technical Services	11	110
Technology Sales	7	86
Total	202	1552
Mean	12	91

Table 3.6: The number of sources used and the number of descriptors for each set in the business model thesaurus.

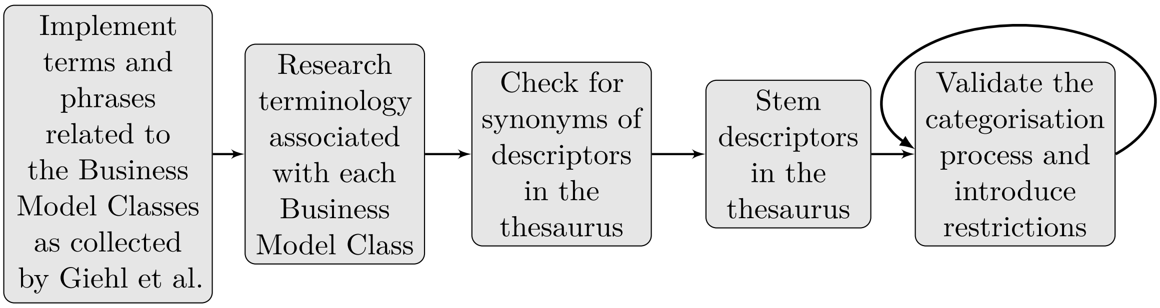


Figure 3.4: The steps involved in the creation of the business model thesaurus.

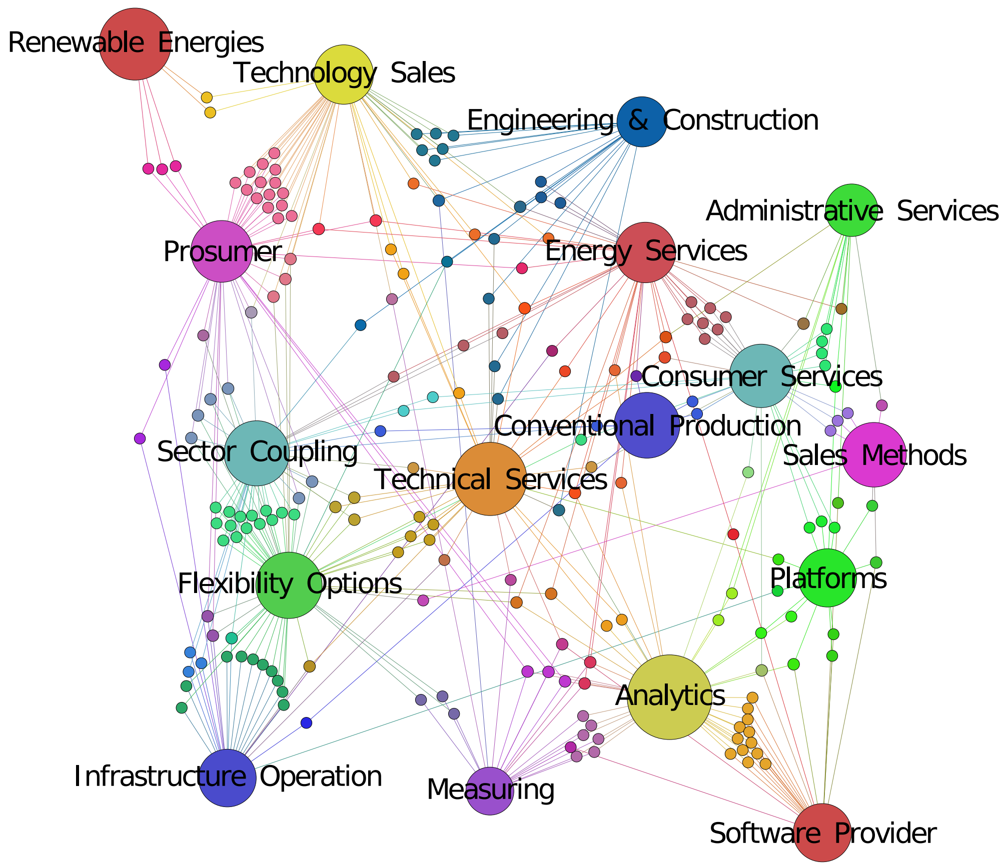


Figure 3.5: The inter-connectivity of the business model classes.

3.4 Categorising the Text Data

Once the text data from the websites had been sufficiently cleaned and structured, and the business model thesaurus was complete, each document in the document matrices was then categorised according to how the business model classes were represented within the text. In order to determine the extent to which a particular business model class was represented, the following procedure was applied:

- For a set in the business model thesaurus each descriptor was checked against the BoW model of a document.
- If a word in the BoW model was equal to or contained a descriptor then this word was tagged for inclusion.
- A value was assigned to the set that was equal to the sum of the frequency of occurrence of each word in the BoW model that had been tagged for inclusion.

This procedure was applied in turn, for each set in the thesaurus to a particular document, and then for each document in all of the document matrices. The result of the application of this procedure was to convert each document matrix of text data (see Table 3.4) into a numerical representation of the extent to which each business model class appeared within each document (see Table 3.8). To apply this procedure three separate, albeit largely equivalent, Python scripts were written to apply the procedure for the unigrams contained in the thesaurus to the unigram documents, and likewise for the bigrams and trigrams. The three resulting matrices were then added together to produce a single complete matrix. The scripts that were written to perform this task were designed to make use of multiple CPUs of a multicore processor. Nonetheless, due to the considerable amount of text data and the number of descriptors making up the business model thesaurus, using 7 of the available 8 CPUs, it took quite a while to complete the categorisation as can be seen in Table 3.7.

	Computation Time
Unigrams	6 days, 3 hours and 34 minutes
Bigrams	1 day, 22 hours and 33 minutes
Trigrams	5 hours and 37 minutes
Total	8 days, 7 hours and 44 minutes

Table 3.7: The time required for the categorisation process.

Following on from this, the numerical representations were normalised so that the results from each website could be compared with the one another. This was done by calculating the value of each cell in the numerical representation matrix as a percentage of the total of each row in the matrix, i.e. the total number of terms in a document that were tagged for inclusion by each set in the thesaurus. This effectively turned the results in Table 3.8 into a normalised version of the same matrix (see Table 3.9) through the application of equation 3.1. It was then this final matrix that formed the basis of the evaluation in the next chapter.

Website	Year	BMC_1	BMC_2	BMC_3	...	BMCn
$1^{st}Website$	2010	x_1	x_2	x_3	...	x_n
	.	.	.	.	.	.
	.	.	.	.	.	.
	.	.	.	.	.	.
	2019	x_1	x_2	x_3	...	x_n

Table 3.8: The numerical representation of each business model class, BMC, within each document.

$$y_i = \frac{x_i}{\sum_{i=1}^{n} x_i} \tag{3.1}$$

Website	Year	BMC_1	BMC_2	BMC_3	...	BMCn
$1^{st}Website$	2010	y_1	y_2	y_3	...	y_n
	.	.	.	.	.	.
	.	.	.	.	.	.
	.	.	.	.	.	.
	2019	y_1	y_2	y_3	...	y_n

Table 3.9: The numerical representation that has been normalised by applying equation 3.1.

In the next chapter the results of the text categorisation are presented in graphical form with some observations provided for each chart.

4 Evaluation

In this chapter the results of the text categorisation are presented. The first section shows the normalised distribution of levels of representation of each of the business model classes on the websites examined for each year from 2010 to 2019. This is presented in a box plot format. In the following section the overall ranking of the mean levels of representation of each business model class are shown for each year. In this section the mean value for the whole of Germany is presented and in addition, a closer look is taken at the different federal states within Germany and the various primary activities of the companies in this study as defined by the NACE rev. 2 codes. For the portrayal of this information the business model class rankings are presented in a heatmap format. The final section examines co-occurrences of the business model classes to see which classes appeared most commonly together as the first and second most represented classes in each year of the study. This information is also presented in a heatmap format.

4.1 Normalised Distribution of Levels of Representation

The box plots in Figures 4.1, 4.2 and 4.3 show the extent to which each business model class was represented on each website from 2010 to 2019. The standard convention for box plots is used in these plots that sees the whiskers of each plot being drawn from the upper quartile (the upper extreme of the box which delineates the point up to which 75% of the data is contained) up to the largest observed point from the dataset that falls within a distance equal to 1.5 times the inter quartile range (the total length of the box). Any points beyond this limit are considered outliers. The red coloured markings indicate the median value of each dataset.

The observable levels of representation of each business model class allow the classes to be loosely categorised into 4 distinct groups. The first group consists solely of the class Renewable Energies. The dominance of the business model class Renewable Energies on company's website content is immediately obvious. This class dominates already in 2010 with a median value of around 8% but frequently accounting for up to almost 35% of the content on company websites. The representation of this class continues to rise up to the time period from 2014 to 2016 and afterwards sees a slight decline while remaining the dominant class and in 2019 continuing to show levels of representation above that of 2010. The second group is defined by those datasets where the upper quartile consistently lies at or above the 5% mark. In this group the business model classes Energy Services, Consumer Services and Technical Services show high and consistent levels of representation throughout the decade. The classes Conventional Production and Prosumer both start the decade with relatively high levels of representation that tend to fall somewhat towards the end of the decade with the larger losses seen in the class of Conventional Production and a drop off in the level of representation of the class Prosumer from the year 2014 onward following an initial rise after 2010. The class Sector Coupling enters this group from 2011 onward but it's levels of representation on websites remains relatively low with the median value never rising much above the 0% mark. A late mover is the class Software Provider, which enters this group around 2015 and, while continuing to have a low median value, shows respectable levels of representation in the median to upper quartile range for the years continuing up to 2019. The third group is defined by datasets whose upper quartile lies consistently below the the 5% mark but which are nonetheless represented within the data. These business model classes generally show levels of representation of less than 3% on 75% of the websites investigated in each year. This includes the classes Sales Methods, Flexibility Options, Analytics, Infrastructure Operations, Engineering & Construction and Technology Sales. The business model classes Measuring and Platforms make up the last group as these classes are generally not represented on company websites except in a few outlying cases.

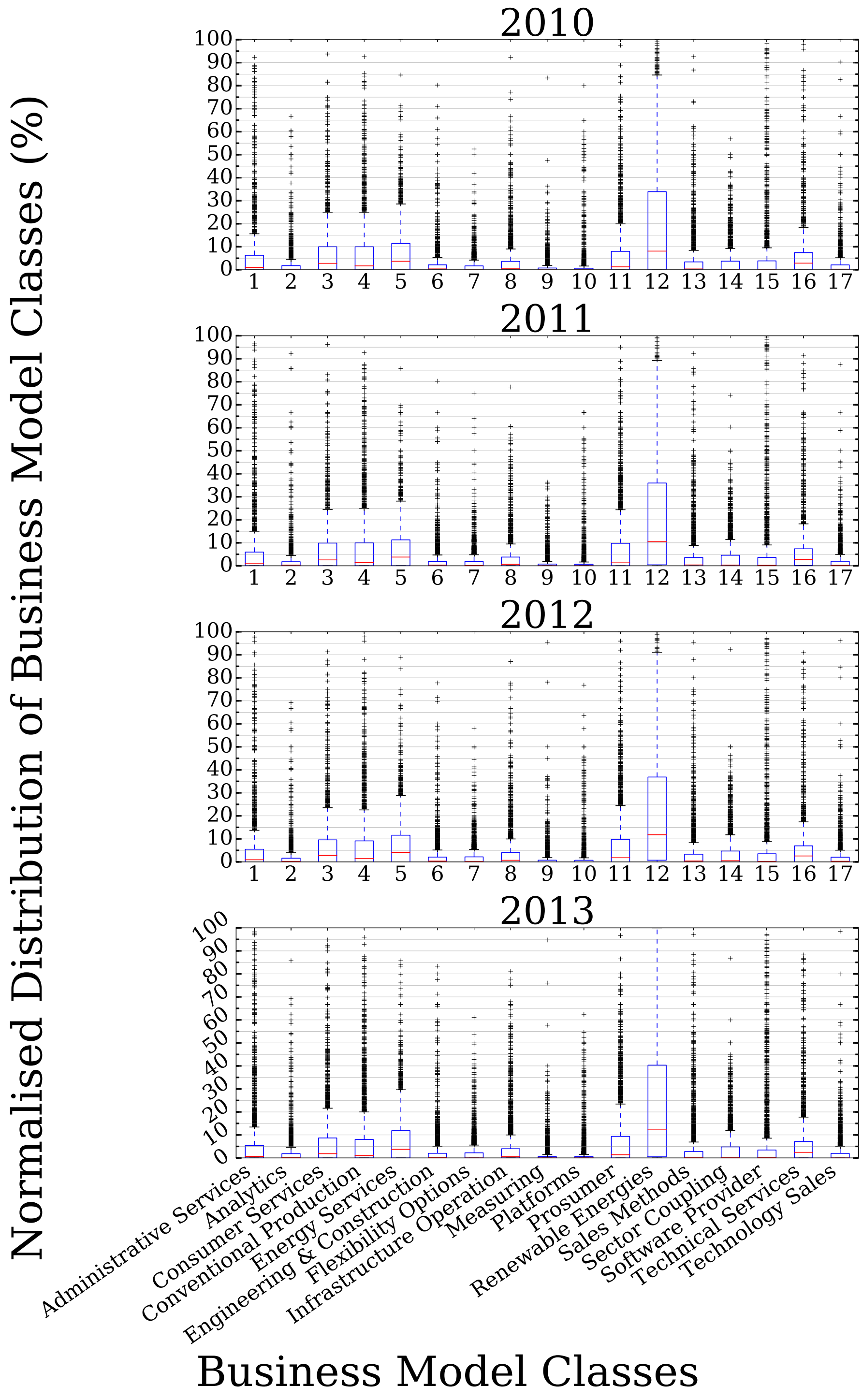


Figure 4.1: Normalised distribution of the business model classes (2010 to 2013).

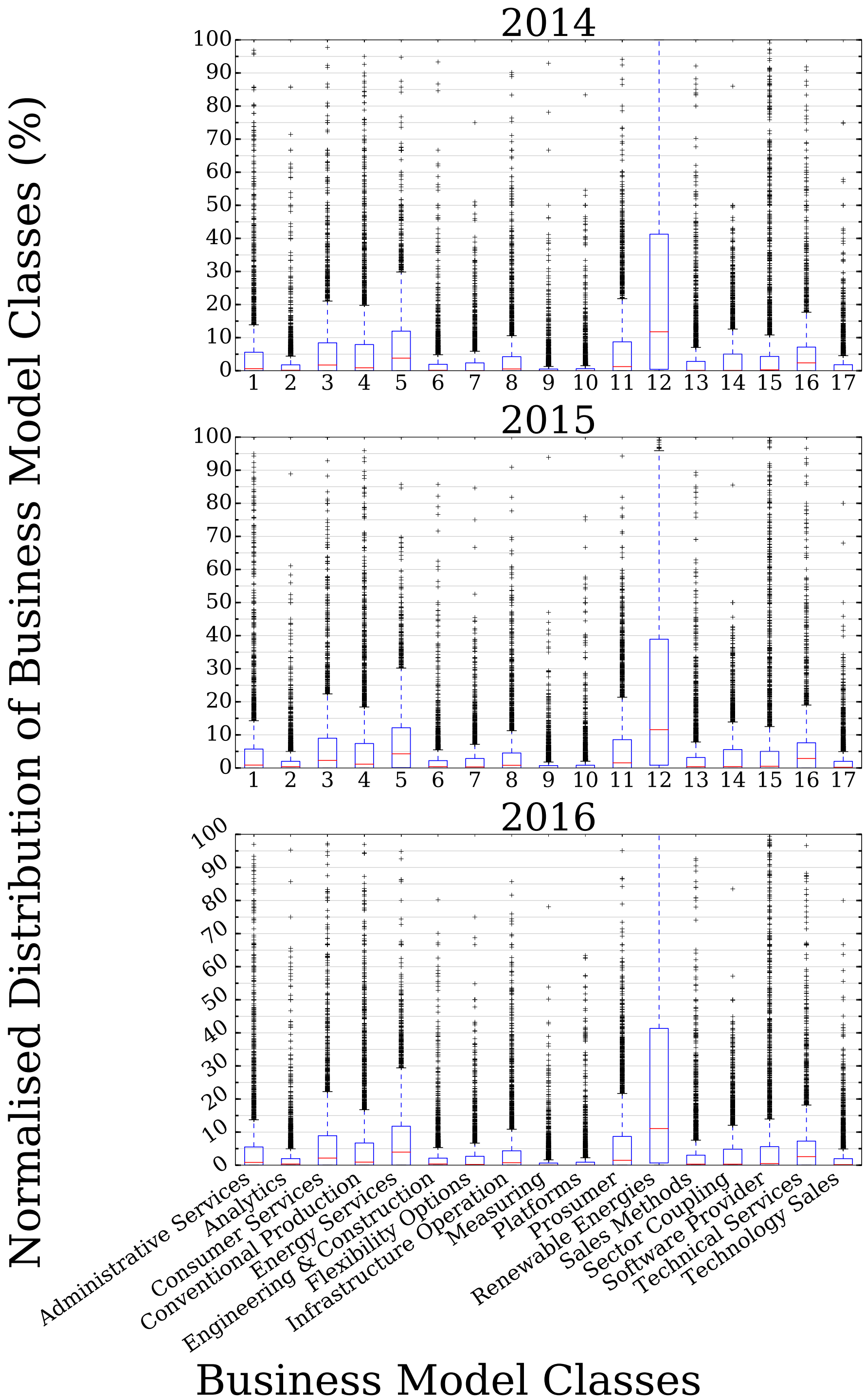


Figure 4.2: Normalised distribution of the business model classes (2014 to 2016).

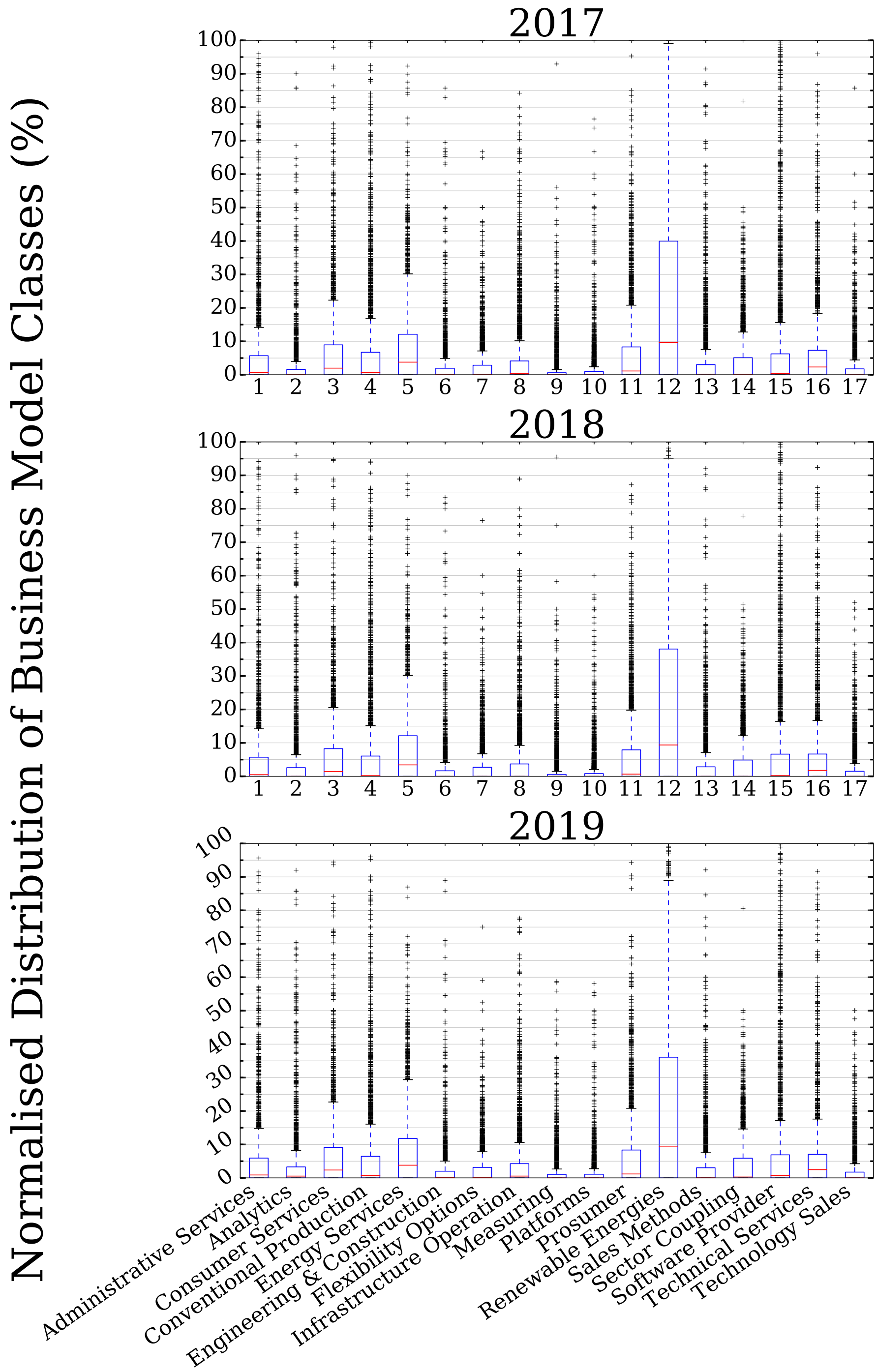


Figure 4.3: Normalised distribution of the business model classes (2017 to 2019).

4.2 Yearly Rankings of Levels of Representation

This section contains charts that show how the ranking of the levels of representation of each business model class changes each year for the whole of Germany, for each individual federal state of Germany and for each of the NACE rev.2 codes assigned to companies in this study as their primary activity. The business model classes are ranked from 1 to 17 with the number 1 corresponding to the highest level of representation and 17 to the lowest. These are based on average values of representation for each business model class per year and each of the ranking charts has an equivalent line plot in Section .3 of the Annex where the absolute mean values can be seen. In each chart the number on each cell denotes the ranking of a business model class for the year indicated on the x-axis. The colour of the cells indicate the change in ranking of a particular business model class in respect to it's ranking in the previous year with green cells indicating a higher ranking than the previous year, red cells indicating a drop in rank compared to the previous year and white cells indicating no change in ranking in comparison with the previous year.

4.2.1 Germany

The yearly ranking of each business model class based on the mean values from the entire dataset, thus representing Germany in it's entirety, can be seen in Figure 4.4. The overall levels of representation remained relatively stable throughout the decade with the highest levels of consistency observed at the extremes of the scale. The class, Renewable Energies, was the most represented of all the classes every year without fail and at the other extreme, the classes Platforms and Measuring rarely strayed far from the bottom of the ranking. The most notable changes across the decade can be seen in the classes Conventional Production and Software Provider. The former dropped from position 2 at the start of the decade to position 6 at the end with a brief, albeit temporal, resurgence in 2018 while the latter started in 2010 in position 7 and from 2014 onward, gradually rose through the ranking order to finish the decade in 2019 as the second most represented business model class. Other changes see the class, Technology Sales, drop 3 points over the decade from place 12 to place 15, while the class, Flexibility Options, gained 3 points over the same time period to go from place 16 to place 13. The class, Analytics, also rose gradually by 3 points over the 10 year period, to place 11, although it also saw the largest single drop of any class when it dropped 3 points in 2012 which it subsequently recovered the following year. Also noteworthy is the class, Prosumer, which saw a surge in it's level of representation in the years 2011 and 2012, where it was the second most represented of the business model classes in 2012, but ultimately finished the decade in the same position as it started, with an overall ranking of 5. In general, all of the classes that were strongly correlated with the provision of services (Administrative Services, Consumer Services, Energy Services, Technical Services) retained relatively stable ranking positions over the decade and always featured amongst the top 10 most represented classes in each year.

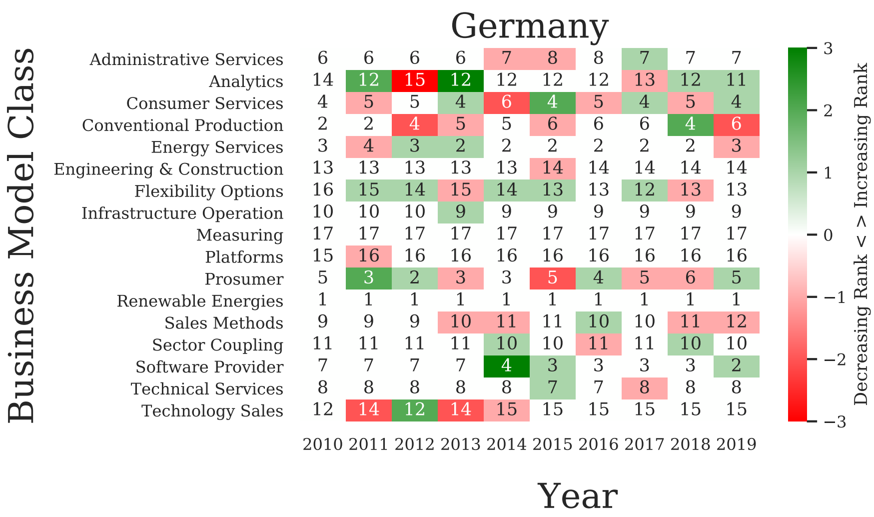


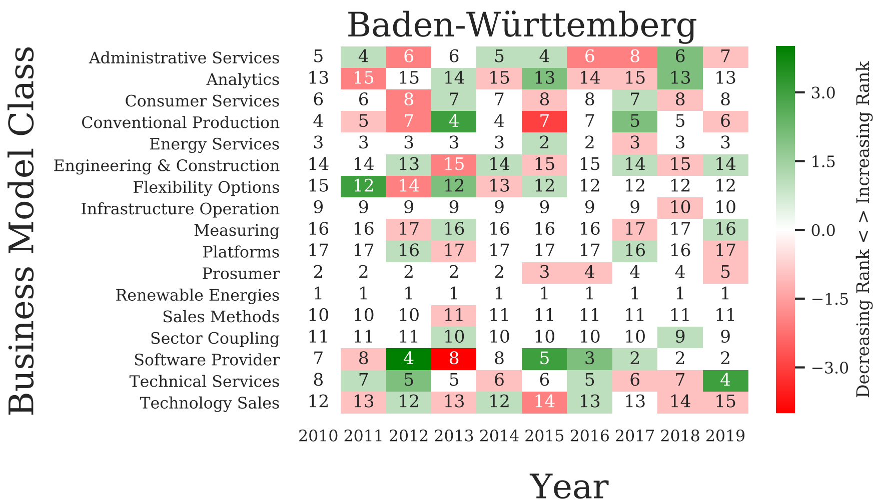
Figure 4.4: Yearly ranking of the business model classes - Germany.

4.2.2 German Federal States

In this section the yearly ranking of the business model classes will be looked at on a state level to see how changes in levels of representation were affected by regional variation.

Baden-Württemberg

The state of Baden-Württemberg (see Figure 4.5) saw the most significant changes in the classes of Prosumer and Software Provider. The class, Prosumer, maintained a position as the second most represented of the classes for the first half of the decade before gradually declining in prominence, while still retaining a relatively high position by 2019. In contrast the class, Software Provider experienced a turbulent first half of the decade with both gains and losses in this time and then subsequently rose in relevance, ending the decade as the second most represented class after Renewable Energies.



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Administrative Services	5	4	6	6	5	4	6	8	6	7
Analytics	13	15	15	14	15	13	14	15	13	13
Consumer Services	6	6	8	7	7	8	8	7	8	8
Conventional Production	4	5	7	4	4	7	7	5	5	6
Energy Services	3	3	3	3	3	2	2	3	3	3
Engineering & Construction	14	14	13	15	14	15	15	14	15	14
Flexibility Options	15	12	14	12	13	12	12	12	12	12
Infrastructure Operation	9	9	9	9	9	9	9	9	10	10
Measuring	16	16	17	16	16	16	16	17	17	16
Platforms	17	17	16	17	17	17	17	16	16	17
Prosumer	2	2	2	2	2	3	4	4	4	5
Renewable Energies	1	1	1	1	1	1	1	1	1	1
Sales Methods	10	10	10	11	11	11	11	11	11	11
Sector Coupling	11	11	11	10	10	10	10	10	9	9
Software Provider	7	8	4	8	8	5	3	2	2	2
Technical Services	8	7	5	5	6	6	5	6	7	4
Technology Sales	12	13	12	13	12	14	13	13	14	15

Figure 4.5: Yearly ranking of the business model classes - Baden-Württemberg.

Bavaria

Bavaria (see Figure 4.6), similar to Baden-Württemberg, was quite stable throughout the decade with the largest gain over the time period being in the class Software Provider which rose by 4 points from a position of 6 in 2010 to being the second most represented class in 2019. The largest loss was seen by the class Conventional Production which, after starting in position 2, ultimately slipped 5 places to end the decade in position 7.

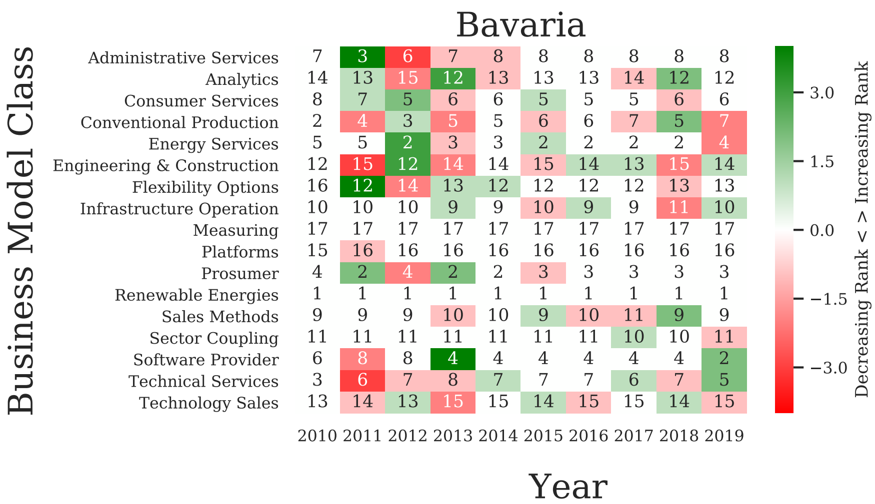
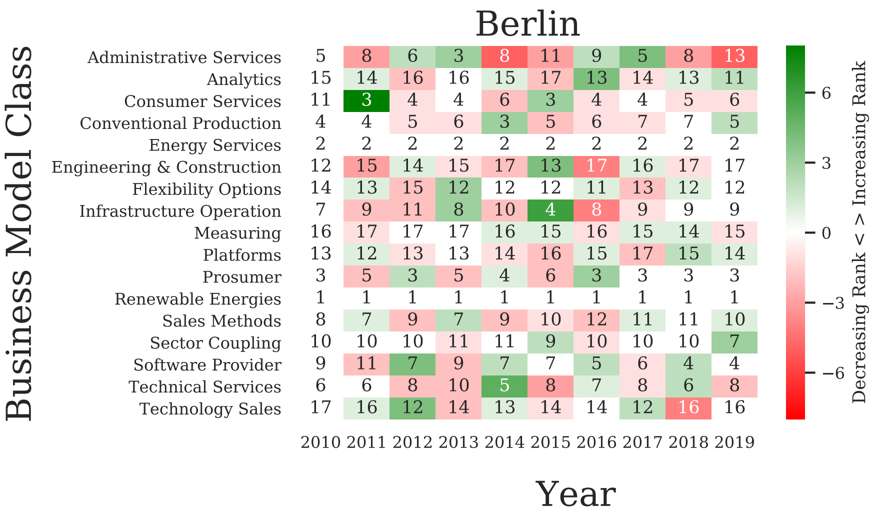


Figure 4.6: Yearly ranking of the business model classes - Bavaria.

Berlin
In Berlin (see Figure 4.7), the class Energy Services was consistently the second most represented class after Renewable Energies and the class, Prosumer, while slipping down a few places in the early and mid part of the decade, was the third most represented for 6 years, including the final 4 years of the decade. The largest gains were seen in the classes Software Provider and Consumer Services, which both rose by 5 points through the rankings in the 10 year period to places 4 and 6, respectively, and the largest losses were seen by the class, Administrative Services, which, after a generally turbulent decade, dropped overall by 8 places to place 13.



Business Model Class	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Administrative Services	5	8	6	3	8	11	9	5	8	13
Analytics	15	14	16	16	15	17	13	14	13	11
Consumer Services	11	3	4	4	6	3	4	4	5	6
Conventional Production	4	4	5	6	3	5	6	7	7	5
Energy Services	2	2	2	2	2	2	2	2	2	2
Engineering & Construction	12	15	14	15	17	13	17	16	17	17
Flexibility Options	14	13	15	12	12	12	11	13	12	12
Infrastructure Operation	7	9	11	8	10	4	8	9	9	9
Measuring	16	17	17	17	16	15	16	15	14	15
Platforms	13	12	13	13	14	16	15	17	15	14
Prosumer	3	5	3	5	4	6	3	3	3	3
Renewable Energies	1	1	1	1	1	1	1	1	1	1
Sales Methods	8	7	9	7	9	10	12	11	11	10
Sector Coupling	10	10	10	11	11	9	10	10	10	7
Software Provider	9	11	7	9	7	7	5	6	4	4
Technical Services	6	6	8	10	5	8	7	8	6	8
Technology Sales	17	16	12	14	13	14	14	12	16	16

Figure 4.7: Yearly ranking of the business model classes - Berlin.

Brandenburg

While there were many small fluctuations in the rankings in Brandenburg (see Figure 4.8), the overall representation of the various business model classes didn't change significantly throughout the decade. The largest single change of any of the classes can be seen by the class, Analytics, which jumped 5 places to position 10 in 2018, only to lose this gain the following year, ending the decade 3 places lower than where it started.

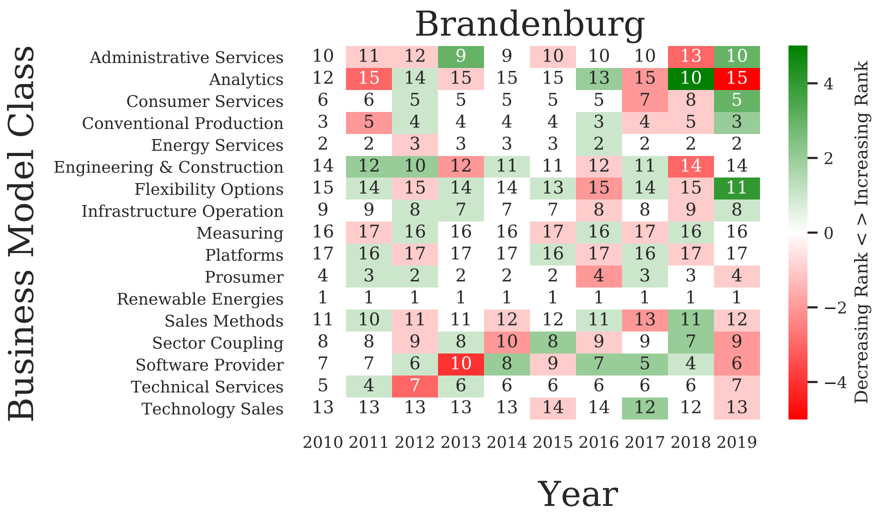
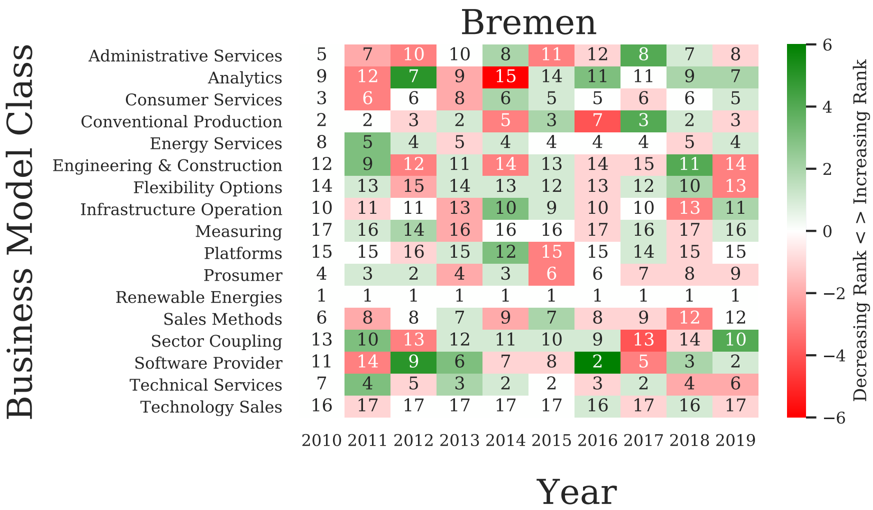


Figure 4.8: Yearly ranking of the business model classes - Brandenburg.

Bremen
The movement of the various classes through the rankings in the city state of Bremen (see Figure 4.9) was generally quite dynamic. The largest gain was seen by the class, Software Provider, which, while seeing losses in some years, rose by 7 points over the 10 year period to end the decade with the second highest mean level of representation. The class, Prosumer, while seeing some gains and remaining in the top 5 ranked classes for the first half of the decade, ultimately fell by 5 places overall and the largest loss of any class in Bremen was by the class, Sales Methods, which, despite brief resurgences in 2013 and 2015, dropped overall by 6 places from an initial ranking of 6 in 2010 to a final ranking of 12 in 2019. Also noteworthy is the class Technical Services, which rose from a starting ranking of 7 in 2010 to being the second most represented class in 2014. This position was maintained until 2017, with the exception of the year 2016 which saw it drop by 1 point, after which time it gradually dropped back down to a position of 6 in the ranking in 2019.



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Administrative Services	5	7	10	10	8	11	12	8	7	8
Analytics	9	12	7	9	15	14	11	11	9	7
Consumer Services	3	6	6	8	6	5	5	6	6	5
Conventional Production	2	2	3	2	5	3	7	3	2	3
Energy Services	8	5	4	5	4	4	4	4	5	4
Engineering & Construction	12	9	12	11	14	13	14	15	11	14
Flexibility Options	14	13	15	14	13	12	13	12	10	13
Infrastructure Operation	10	11	11	13	10	9	10	10	13	11
Measuring	17	16	14	16	16	16	17	16	17	16
Platforms	15	15	16	15	12	15	15	14	15	15
Prosumer	4	3	2	4	3	6	6	7	8	9
Renewable Energies	1	1	1	1	1	1	1	1	1	1
Sales Methods	6	8	8	7	9	7	8	9	12	12
Sector Coupling	13	10	13	12	11	10	9	13	14	10
Software Provider	11	14	9	6	7	8	2	5	3	2
Technical Services	7	4	5	3	2	2	3	2	4	6
Technology Sales	16	17	17	17	17	17	16	17	16	17

Figure 4.9: Yearly ranking of the business model classes - Bremen.

Hamburg

Hamburg (see Figure 4.10), another city state, also had a dynamic and turbulent decade in terms of the ranking orders of the business model classes although the end of decade saw many of the classes return to positions similar to where they started in 2010. One notable exception to this trend was the class Conventional Production, which, contrary to the national trend, started out in a comparatively low position in place 7 and gradually became more prominent, despite somewhat of a crash in 2015, ending the decade as the third most represented class. Such crashes are a prominent feature of the business model class rankings in Hamburg with the class; Analytics, crashing 3 times by either 4 or 5 places in 2012, 2016 and 2019, the class, Consumer Services, crashing by 4 places in 2011 only to gradually recover it's previous raking. The class, Prosumer, similarly crashed 4 places in 2016 and 2018, continuing a trend of gradual decline that saw it lose 4 places in the ranking overall across the 10 year period. Crashes can also be seen in the classes Software Provider and Technical Services, which both experience 2 crashes and both later recover to finish the decade in the same position as they started with the class, Software Provider, being the second most represented of the classes in 2011 and for 3 further years in the middle of the decade.

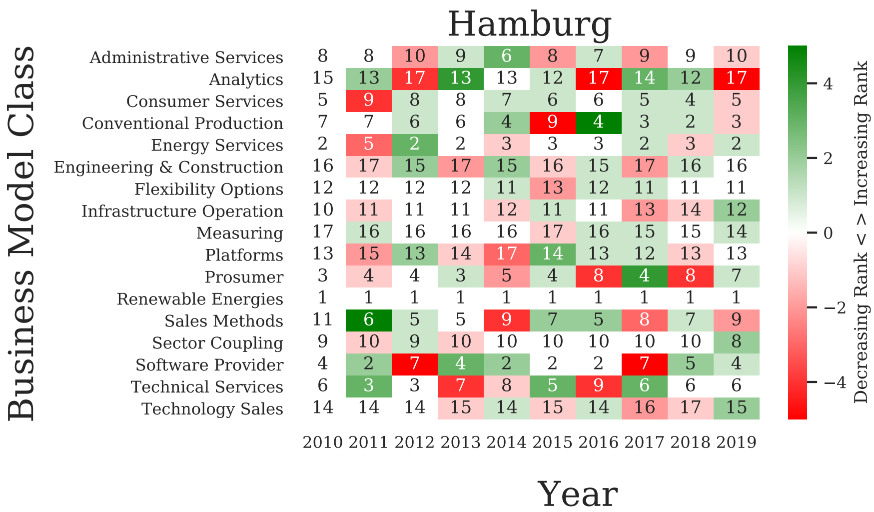


Figure 4.10: Yearly ranking of the business model classes - Hamburg.

Hesse

The movement of the ranking orders in the state of Hesse (see Figure 4.11) was quite dynamic without being hectic as most of the change in the rankings involved relatively small incremental steps. The largest change of any one class over the decade was by the class, Analytics, which rose a total of 6 places to go from being the second least represented class in 2010 to being the tenth most represented class in 2019. The biggest loss in Hesse was seen by the class, Consumer Services, which started the decade as the second most represented class but gradually dropped, despite a few resurgences, by 4 points to place 6. A similar loss of 4 points overall was seen by the class, Platforms, which, while never actually placing particularly highly, occupied a ranking of 13 in 2010 only to drop through the ranks and become the least represented of all of the business model classes for the final 3 years of the decade.

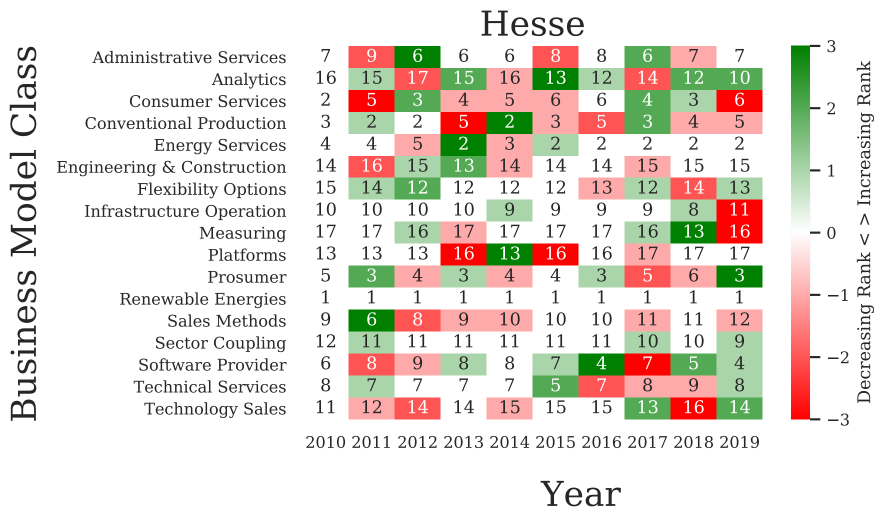


Figure 4.11: Yearly ranking of the business model classes - Hesse.

Lower Saxony

The class rankings in Lower Saxony (see Figure 4.12) were quite stable throughout the entire time period. The biggest gains were seen by the class, Software Provider, which after rising 5 places in 2014 to place 2, eventually finished the decade as the third most represented class, 4 places higher than where it started in 2010. The years 2015 to 2016 saw a shift, where the class, Administrative Services, started to feature less prominently while the class, Technical Services, started to see an increase in it's levels of representation, ultimately ending the decade as the second most represented business model class. The biggest loser over the course of the decade was the class, Sales Methods, which dropped by 5 points from place 8 in 2010 to place 13 in 2019.

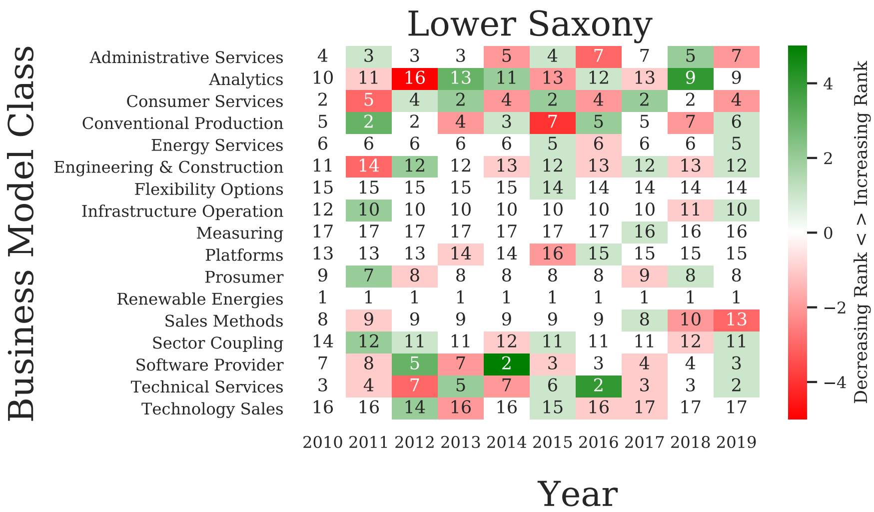


Figure 4.12: Yearly ranking of the business model classes - Lower Saxony.

Mecklenburg-Western Pomerania

The state of Mecklenburg-Western Pomerania (see Figure 4.13) saw quite a bit of change in the overall rankings over the 10 years from 2010 to 2019. The most upwardly mobile of the business model classes were, Analytics, which saw a rise of 5 points from place 14 in 2010 to place 9 in 2019 and Software Provider, which saw a fairly steady rise throughout the decade to climb 9 points overall from a starting position of 11 to being the second most represented class in both 2016 and 2019. Losses were seen by the classes Administrative Services and Consumer Services, which both started the decade in places 2 and 3, respectively, and both continued to drop over the period to places 6 and 8, and the class, Technology Sales, which dropped a total of 5 points from place 10 in 2010 to place 15 in 2019.

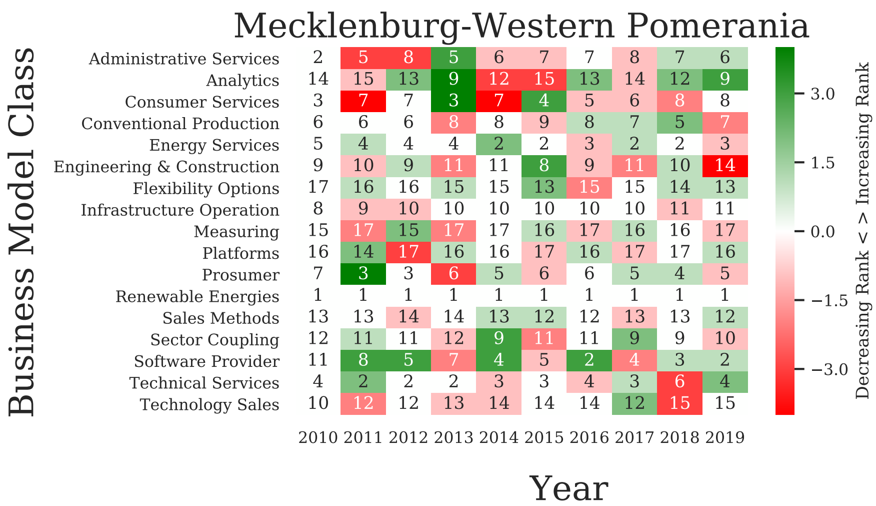


Figure 4.13: Yearly ranking of the business model classes - Mecklenburg-Western Pomerania.

North Rhine-Westphalia

In North Rhine-Westphalia (see Figure 4.14), the ranking orders remained quite stable with gains and losses usually being minor and, in many cases, short-lived. The largest movements amongst the top 10 most represented classes see the class, Administrative Services, gain 3 points in the second half of the decade to end up as the fifth most represented class, and the class, Conventional Production, gradually drop by 3 points from 2013 onward to end up in place 6 in 2019.

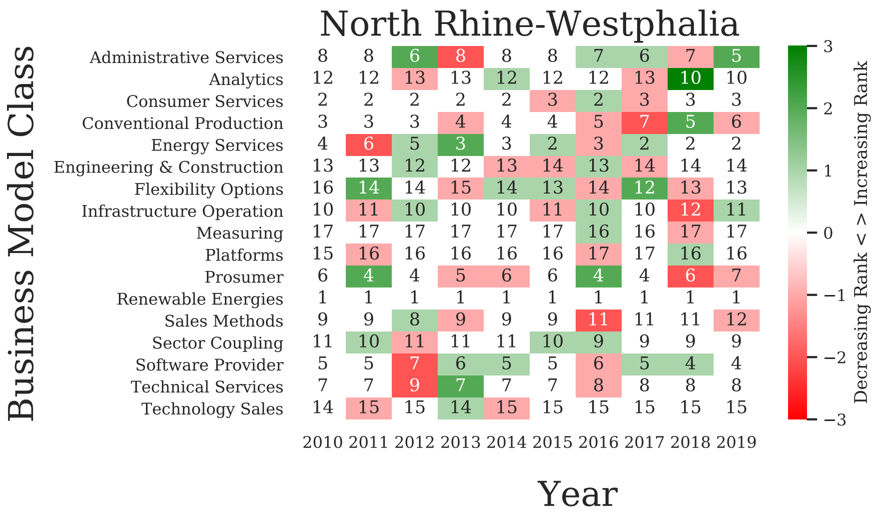


Figure 4.14: Yearly ranking of the business model classes - North Rhine-Westphalia.

Rhineland-Palatinate

The state of Rhineland-Palatinate (see Figure 4.15) saw the top 5 placed classes display relative stability with the exception of the class, Software Provider, which, in contrast to the case in many other federal states, and also the national average, had a volatile first half of the decade and eventually dropped 2 places overall from it's starting place of 5 in 2010. Also, the class, Conventional Production, while consistently being the third most represented class dropped by 3 places both in 2013 and 2015 only to subsequently regain it's position the following year in each case. The biggest changes in the top 10 ranked classes were the gradual gain of 3 places by the class, Prosumer, to move into place 6 by 2019, and the loss of 3 places by the class, Technical Services, which dropped from place 6 in 2010 to place 9 in 2019, albeit with a period of increased representation in 2014 and 2015.

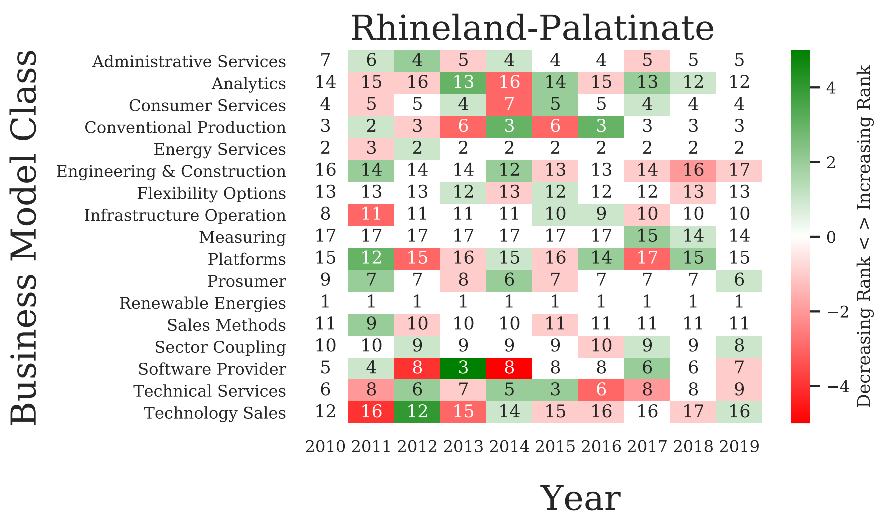


Figure 4.15: Yearly ranking of the business model classes - Rhineland-Palatinate.

Saarland

The results from the Saarland region (see Figure 4.16) are somewhat unique in that this is the only instance where the class, Renewable Energies, is not consistently the most represented class in every year, although it does assume this position in 2013 and retains it for the rest of the decade. The first 3 years of the decade see the class, Conventional Production, as the most represented class and it continues to have a strong presence, occupying the second place position from 2013 onward, diverging from the national trend. The rankings in Saarland are also characterised by repeated instances of large gains followed by similarly large losses. This can be observed in the classes Analytics, Consumer Services, Software Provider and Technical Services. The largest overall shift in position was by the class, Flexibility Options, which finished the decade in place 10, 6 points higher than where it started in 2010, and the largest decline saw the class, Technology Sales, go from occupying place 10 in 2010 to dropping 5 places by 2019 to place 15. The class, Infrastructure Operation, also experienced gains over the time period to rise a total of 4 places, finishing the decade in an unusually high position as the third most represented of the business model classes.

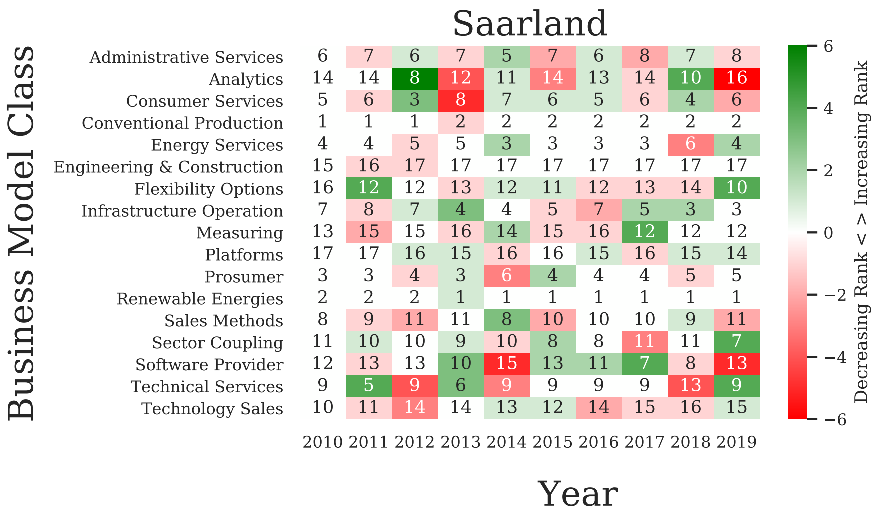


Figure 4.16: Yearly ranking of the business model classes - Saarland.

Saxony-Anhalt

Overall, high levels of stability can be seen amongst the ranking of the classes in the state of Saxony-Anhalt (see Figure 4.17). The largest shifts across the decade take place at the lower end of the ranking with the class, Analytics, gaining 5 places to go from place 14 to place 9 and the class, Technology Sales, dropping 4 places from place 13 to being the least represented class in 2018 and 2019. At the upper end of the ranking, the class, Software Provider, gained 2 points to end up in place 3 while the class, Conventional Production, lost 2 points, ending up in place 4. No other class shifted by more than 1 position overall in the 10 year period.

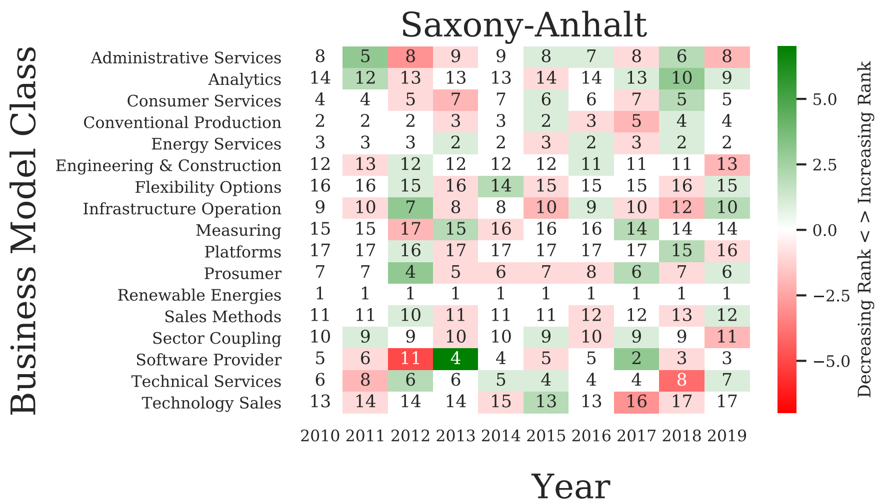


Figure 4.17: Yearly ranking of the business model classes - Saxony-Anhalt.

Saxony

In the state of Saxony (see Figure 4.18), the most significant movement can be seen by the class, Software Provider, which, after initially dropping 2 places in 2011, gained a total of 6 points over the decade to end up as the third most represented class in 2018 and 2019 despite a slump in 2016. Also, the class, Administrative Services, saw an overall gain of 4 places after an initial jump of 6 places in 2013 and 2 subsequent slumps and recoveries to end up as the fourth most represented class in 2019. The most significant loss can be seen by the class, Conventional Production, which saw a gradual, relatively steady decline throughout the decade from place 2 to place 5.

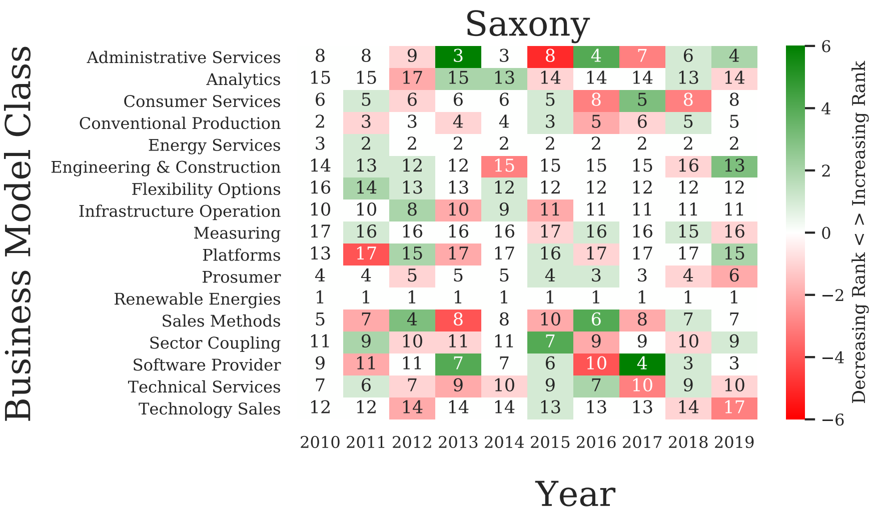
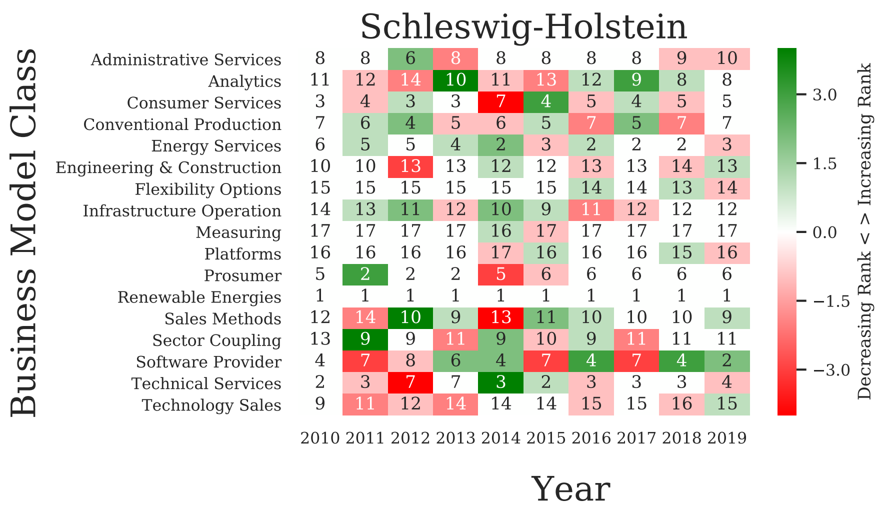


Figure 4.18: Yearly ranking of the business model classes - Saxony.

Schleswig-Holstein
In Schleswig-Holstein (see Figure 4.19), gains were made by the class, Energy Services, which moved up 4 places between 2010 and 2014 and remained in either position 2 or 3 for the remainder of the decade. Also the classes, Analytics and Sales Methods, experienced both losses and gains in the early part of the time period which culminated in increased stability and overall gains in the later part of the time period with both classes ultimately moving up by 3 places to end the decade in positions 8 and 9, respectively. The greatest losses were made by the classes Technology Sales and Engineering & Construction, both of which began the decade in the top 10 of the most represented classes in positions 9 and 10, respectively. By the end of the decade the class, Engineering & Construction, had fallen by 3 places while the class, Technology Sales, had fallen by 6 places. The class, Technical Services, saw a level of representation higher than the national average and was amongst the top 3 most represented classes for a total of 7 years despite a slump in 2012 and 2013.



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Administrative Services	8	8	6	8	8	8	8	8	9	10
Analytics	11	12	14	10	11	13	12	9	8	8
Consumer Services	3	4	3	3	7	4	5	4	5	5
Conventional Production	7	6	4	5	6	5	7	5	7	7
Energy Services	6	5	5	4	2	3	2	2	2	3
Engineering & Construction	10	10	13	13	12	12	13	13	14	13
Flexibility Options	15	15	15	15	15	15	14	14	13	14
Infrastructure Operation	14	13	11	12	10	9	11	12	12	12
Measuring	17	17	17	17	16	17	17	17	17	17
Platforms	16	16	16	16	17	16	16	16	15	16
Prosumer	5	2	2	2	5	6	6	6	6	6
Renewable Energies	1	1	1	1	1	1	1	1	1	1
Sales Methods	12	14	10	9	13	11	10	10	10	9
Sector Coupling	13	9	9	11	9	10	9	11	11	11
Software Provider	4	7	8	6	4	7	4	7	4	2
Technical Services	2	3	7	7	3	2	3	3	3	4
Technology Sales	9	11	12	14	14	14	15	15	16	15

Figure 4.19: Yearly ranking of the business model classes - Schleswig-Holstein.

Thuringia
The greatest gains by far in the state of Thuringia (see Figure 4.20) were made by the class, Software Provider, which saw a rapid and steady rise through the rankings from 2011 onward, to end up as the second most represented class in 2016, a position that was then largely maintained for the rest of the decade, albeit with a 2 point decrease in the ranking in 2018. The class, Technical Services, rose relatively steadily in rank throughout the decade before crashing in 2019. The most significant loss can be seen by the class, Sales Methods, which saw a period of growth in 2011 and 2012, moving from place 8 to place 5, before ultimately dropping down through the ranks to finish the decade in place 12. Also of note is the class, Consumer Services, which experienced a volatile decade, frequently bouncing in and out of the top 5 ranking.

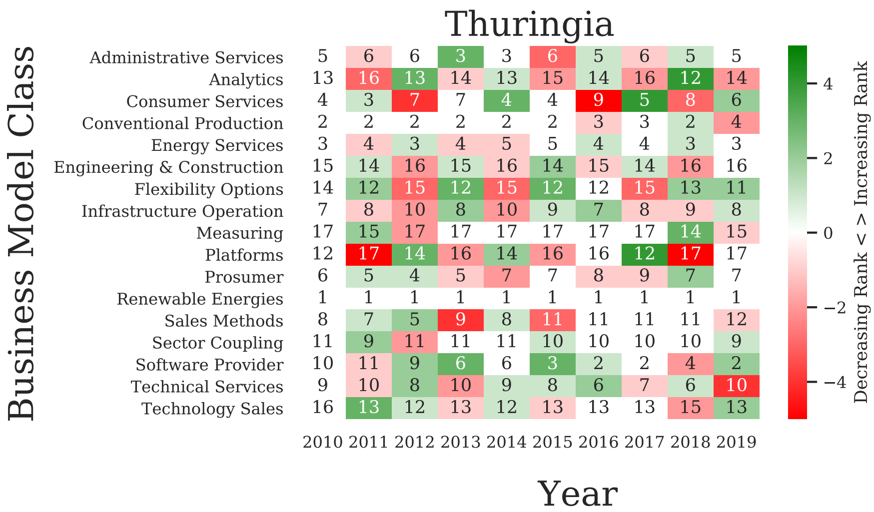


Figure 4.20: Yearly ranking of the business model classes - Thuringia.

The business model classes that experienced the greatest overall increases and decreases in ranking over the 10 year period are displayed in Table 4.1. Here it can be seen that the class, Software Provider, was most often the class that had the highest increase in ranking in each federal state, having the highest, or joint highest, increase in ranking in 8 of the 16 federal states of Germany. The classes, Analytics and Flexibility Options, appeared second most frequently as having either the highest or joint highest increase in ranking, each appearing 3 times. The classes that most commonly had the largest decrease in ranking were the class, Technology Sales, which appears 7 times, followed by the class, Sales Methods, which appears 3 times.

	Greatest overall increase in rank		Greatest overall decrease in rank	
State	Business model class	Places increased	Business model class	Places decreased
Baden-Württemberg	Software Provider	5	Prosumer, Technology Sales	3
Bavaria	Software Provider	4	Conventional Production	5
Berlin	Software Provider, Consumer Services	5	Administrative Services	8
Brandenburg	Flexibility Options	4	Analytics	3
Bremen	Software Provider	9	Sales Methods	6
Hamburg	Conventional Production	4	Prosumer	4
Hesse	Analytics	6	Consumer Services, Platforms	4
Lower Saxony	Software Provider	4	Sales Methods	5
Mecklenburg-Western Pomerania	Software Provider	9	Consumer Services, Engineering & Construction, Technology Sales	5
North Rhine-Westphalia	Administrative Services, Flexibility Options	3	Conventional Production, Sales Methods	3
Rhineland-Palatinate	Prosumer, Measuring	3	Technology Sales	4
Saarland	Flexibility Options	6	Technology Sales	5
Saxony-Anhalt	Analytics	5	Technology Sales	4
Saxony	Software Provider	6	Technology Sales	5
Schleswig-Holstein	Energy Services, Analytics, Sales Methods	3	Technology Sales	6
Thuringia	Software Provider	8	Platforms	5

Table 4.1: Greatest changes in overall ranking from 2010 to 2019 in each federal state

4.2.3 NACE rev.2 Primary Codes

In this section the codes from the NACE classification system that were cited by companies as being their primary activity are focused on to examine if, and to what extent, this has an effect on the yearly ranking of the business model classes.

3511-Production of electricity
This section of the NACE codes (see Figure 4.21) accounted for over 60% of all the companies included in this study and displayed remarkable stability over the course of the decade. This section includes: operation of generation facilities that produce electric energy; including thermal, nuclear, hydroelectric, gas turbine, diesel and renewable and excludes the production of electricity through incineration of waste [44]. In this group the most significant gains were made by the class, Software Provider, which rose by 3 places in 2011 into position 3, where it remained until 2018 before becoming the second most represented class in 2018 and 2019. The class, Flexibility Options, also rose by 4 places over the first part of the decade until 2015 to reach place 12 after which it's position largely stabilised, and the class, Analytics, after being in place 14 for most of the decade jumped by 5 places in 2018 to place 9 where it remained in 2019. The class, Technical Services, displayed levels of representation higher than the national average although it's ranking level dropped by 2 places from place 3 to place 5 over the time period. Also in contrast to the national average were the classes, Conventional Production, which saw below average levels of representation and variation, remaining in position 8 throughout the decade, and, Prosumer, which typically saw lower levels of variation and higher levels of ranking compared to the national average for the time period and was the second most represented class for most of the decade before dropping by 1 place in 2018. The class, Infrastructure Operation, rose by 3 points to place 11 in 2011 but ultimately lost this gain from 2017 onward. Other losses throughout the decade can be seen by the classes, Engineering & Construction and Technology Sales, which dropped by 3 places to 13 and 4 places to 15, respectively.

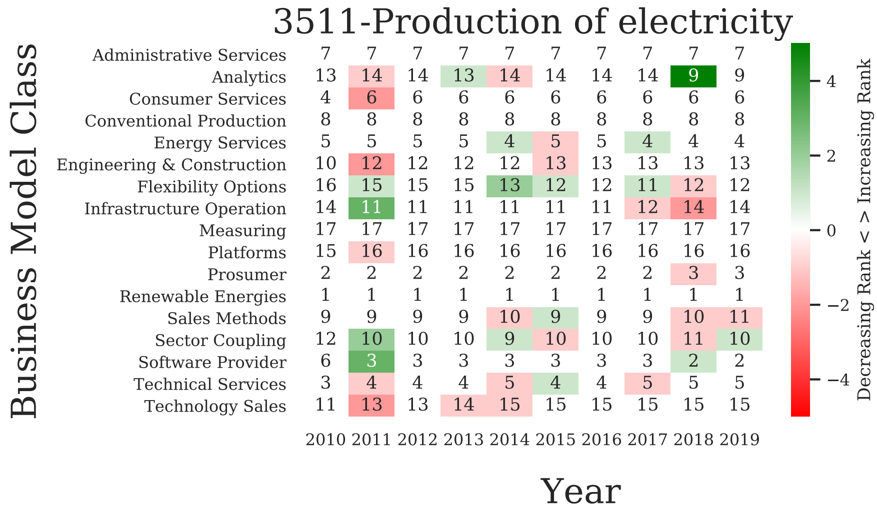


Figure 4.21: Yearly ranking of the business model classes - 3511-Production of electricity.

3500-Electricity, gas, steam and air conditioning supply
This section (see Figure 4.22) accounted for around 8% of the companies and changes in the rankings over the time period were generally minor fluctuations that saw most of the classes finish the decade close to where they started it. This section includes: provision of electric power, natural gas, steam, hot water and the like through a permanent infrastructure (network) of lines, mains and pipes; distribution of electricity, gas, steam, hot water and the like in industrial parks or residential buildings; operation of electric and gas utilities, which generate, control and distribute electric power or gas; and provision of steam and air-conditioning supply [44]. The top 3 most represented classes stayed constant over the 10 year period and these were, Renewable Energies, Energy Services and Conventional Production, respectively. Notable movers were the class, Administrative Services, which saw a gradual decrease in ranking from 2014 onward, albeit with a resurgence in 2018, to ultimately drop 3 places over the decade from place 7 to 10 and the class, Sector Coupling, which saw little variation for most of the decade but moved up 4 places in 2019 to place 6. Also noteworthy is the class, Infrastructure Operation, which saw a period of steady increase from to 2011 to 2016 where it moved up by 5 places through the rankings, only to drop by 3 places again by 2018, and the class, Flexibility Options, which moved up 4 places from place 16 to place 12 between 2010 and 2012 and for the most part maintained this position for the remainder of the decade.

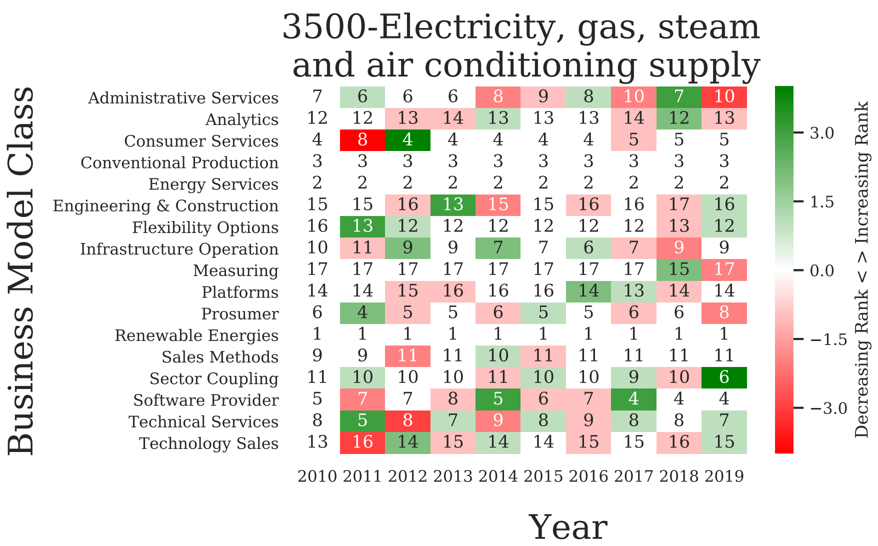


Figure 4.22: Yearly ranking of the business model classes - 3500-Electricity, gas, steam and air conditioning supply.

3513-Distribution of electricity

Companies declaring distribution of electricity (see Figure 4.23) as their primary activity made up around 7.5% of the total and this section includes: operation of distribution systems (i.e., consisting of lines, poles, meters, and wiring) that convey electric power received from the generation facility or the transmission system to the final consumer [44]. Amongst this group, the class, Conventional Production, was the most represented for a total of 7 years and second most represented for the remaining 3 years. The class, Renewable Energies, was the next most represented of the classes, consistently being amongst the top 3 ranking classes, and the class, Energy Services, was the third most represented class overall. The class, Infrastructure Operation, ranked consistently in place 4, a value higher than the national average for this class. Also showing uncharacteristically high levels of representation was the class, Measuring, which was either in place 12 or 13 for the whole time period. The classes, Sector Coupling and Flexibility Options, both had the greatest gains overall across the 10 year period, each moving up 2 places, from place 10 to place 8 and from place 15 to place 13, respectively and the greatest overall drop in ranking was by the class, Technology Sales, which dropped 3 places between 2010 and 2019 from place 12 to place 15.

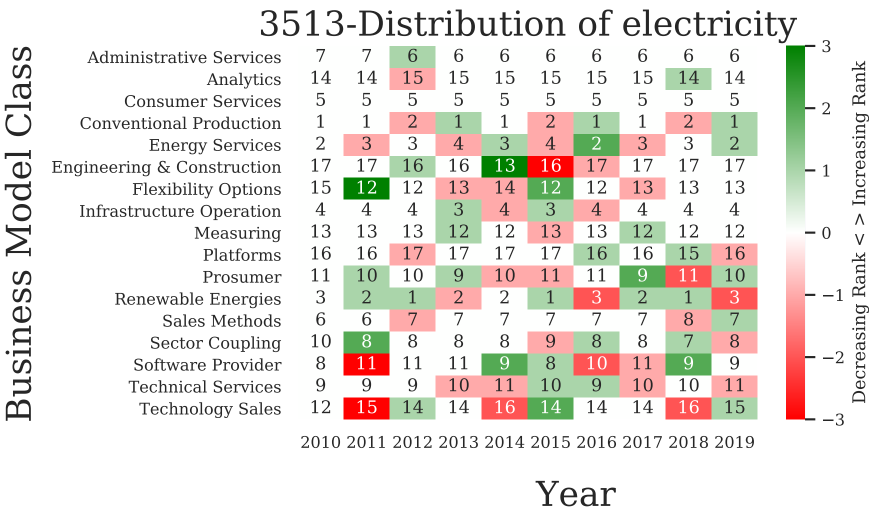


Figure 4.23: Yearly ranking of the business model classes - 3513-Distribution of electricity.

3530-Steam and air conditioning supply
The section, steam and air conditioning supply (see Figure 4.24), contained 6.4% of the companies in this study and includes: production, collection and distribution of steam and hot water for heating, power and other purposes; production and distribution of cooled air; production and distribution of chilled water for cooling purposes; and production of ice, for food and non-food (e.g. cooling) purposes [44]. The most represented of the business model classes in this group was Energy Services, which moved up from place 2 in 2013 to replace the class Renewable Energies and maintained the top position until 2019. The class, Renewable Energies, then remained in place 2, making it the second most represented class. The third most represented class was the class, Sector Coupling, which moved up from place 5 during the first 4 years of the decade and remained in place 3 until 2019. This was a ranking high above the national average for this class. The largest gain in this group was by the class, Analytics, which rose by 4 places over the decade, starting in place 15 in 2010 and ending up in place 11 by 2018, and the most significant loss in this group was by the class, Administrative Services, which started with a ranking of 3 in 2010 but dropped 2 places in 2012 and eventually ended up in place 6 by 2019.

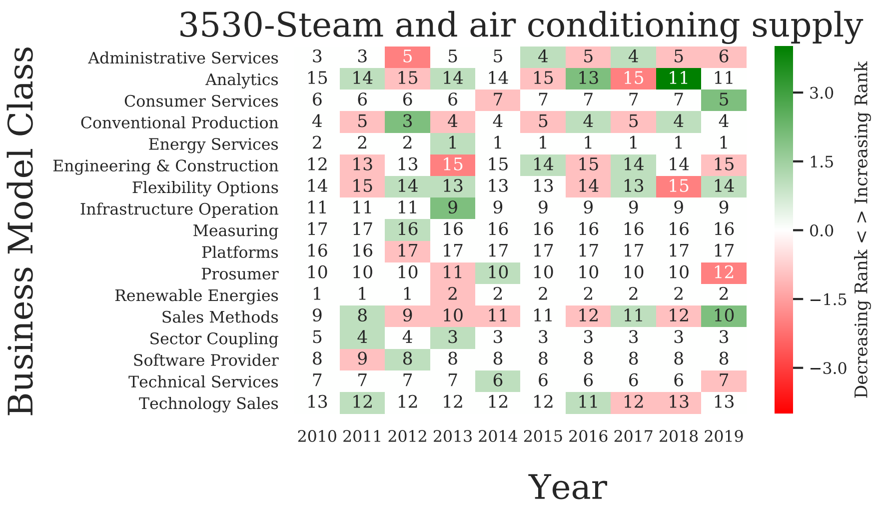


Figure 4.24: Yearly ranking of the business model classes - 3530-Steam and air conditioning supply.

3521-Manufacture of gas

Manufacture of gas (see Figure 4.25) was cited as the primary activity of some 5.7% of the companies in this study. This section includes: production of gas for the purpose of gas supply by carbonation of coal, from by-products of agriculture or from waste; and manufacture of gaseous fuels with a specified calorific value, by purification, blending and other processes from gases of various types including natural gas. Excluded from this section are: production of crude natural gas; operation of coke ovens; manufacture of refined petroleum products; and manufacture of industrial gases [44]. This group also displayed high levels of stability with many minor shifts in ranking from year to year but little significant change to the overall ranking. Gains were seen by the class, Software Provider, which initially dropped in ranking after 2010 by 2 places to place 7, but subsequently returned to place 5 by 2015 and was the second most represented class in 2018 and 2019. Similarly, the class Analytics fell from place 10 to place 14 during the first 3 years of the decade, then after remaining outside of the top 10 ranking until 2018, placed 7 in 2018 and 2019. Losses were seen by the classes, Administrative Services, which saw an initial drop in the level representation at the start of the decade and later another drop at the end of the decade to finally move a total of 4 points down from position 4 to position 8 over the time period, and Sales Methods, which fell through the rankings every year from 2010 to 2014, and then stabilised after a slight resurgence in 2015 and 2016 to finish the decade 3 places lower than place 8, where it started in 2010.

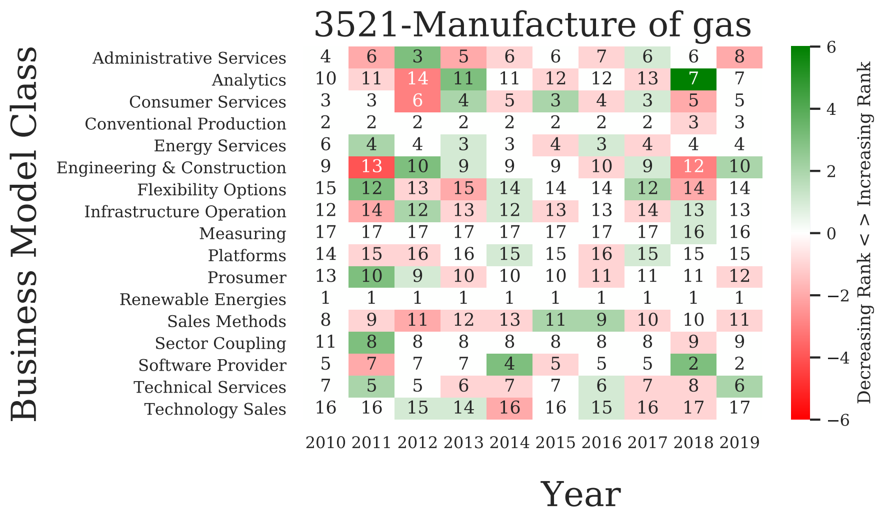


Figure 4.25: Yearly ranking of the business model classes - 3521-Manufacture of gas.

3510-Electric power generation, transmission and distribution
This section (see Figure 4.26) made up around 3% of the total sample and includes: the generation of bulk electric power; transmission from generating facilities to distribution centres; and distribution to end users [44]. The most represented class in this group overall was the class, Conventional Production, which was the highest ranking class for 8 years in total and in 2016 and 2017 ranked second. During these years the highest ranking class was the class, Consumer Services, which saw much mobility within the top 4 ranks during the decade with 5 years in total as either the first or the second most represented class. For most of the decade the class, Renewable Energies, placed either second or third, although it started and ended the decade in place 4. The class, Software Provider, while remaining in place 11 for most of the decade, experienced the largest gains and losses of any class when it dropped 5 places to place 16 for 1 year in 2012 and later rose 4 places to place 7, again for 1 year, in 2017. The largest overall gains were by the class, Flexibility Options, which rose from place 16 in 2010 to place 12 by 2014 and maintained this position for the remainder of the 10 year period, and the largest losses were by the classes, Technology Sales and Engineering & Construction, each of which dropped 3 places from place 12 to place 15 and from place 14 to place 17, respectively.

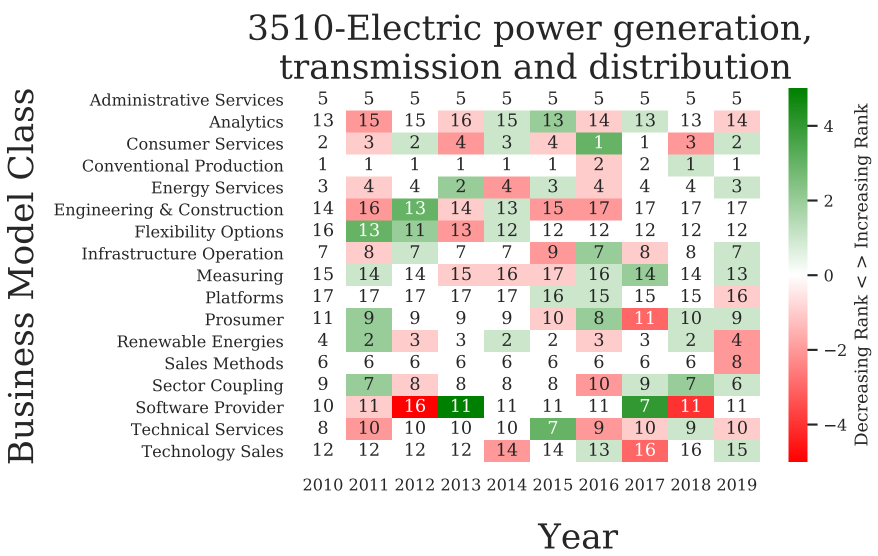
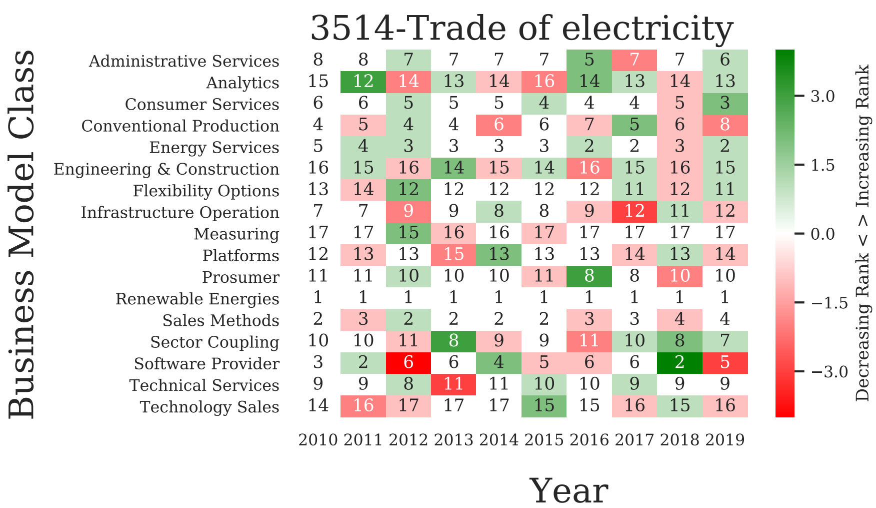


Figure 4.26: Yearly ranking of the business model classes - 3510-Electric power generation, transmission and distribution.

3514-Trade of electricity

Some 2% of the companies in this study cited, trade of electricity (see Figure 4.27), as their primary activity. This section includes: sale of electricity to the user; activities of electric power brokers or agents that arrange the sale of electricity via power distribution systems operated by others; and operation of electricity and transmission capacity exchanges for electric power [44]. In this section the class, Sales Methods, saw a level of representation higher than it's national average, being the second most represented class for most of the first half of the decade and, while dropping 2 places by 2019, consistently ranking amongst the top 5 classes. The classes, Energy Services and Consumer Services, both saw steady increases in the levels of representation throughout the decade, both rising by 3 points overall from 5 to 2 and 6 to 3, respectively. Gains were also made by the class, Sector Coupling, which gained 3 places overall by the end of the decade, to end up in place 7, after making gains initially in 2012 that were subsequently lost over the following 3 years. The class, Software Provider, saw high levels of representation at the start and end of the decade, being the second most represented class overall in 2011 and 2018, and although these high rankings were short-lived, consistently ranked amongst the top 6 classes. Losses were seen by the classes, Conventional Production and Infrastructure Operation, which both saw relatively steady levels of decline from the start to middle of the decade onward, and which dropped 4 places to 8 and 5 places to 12, respectively.



Business Model Class	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Administrative Services	8	8	7	7	7	7	5	7	7	6
Analytics	15	12	14	13	14	16	14	13	14	13
Consumer Services	6	6	5	5	5	4	4	4	5	3
Conventional Production	4	5	4	4	6	6	7	5	6	8
Energy Services	5	4	3	3	3	3	2	2	3	2
Engineering & Construction	16	15	16	14	15	14	16	15	16	15
Flexibility Options	13	14	12	12	12	12	12	11	12	11
Infrastructure Operation	7	7	9	9	8	8	9	12	11	12
Measuring	17	17	15	16	16	17	17	17	17	17
Platforms	12	13	13	15	13	13	13	14	13	14
Prosumer	11	11	10	10	10	11	8	8	10	10
Renewable Energies	1	1	1	1	1	1	1	1	1	1
Sales Methods	2	3	2	2	2	2	3	3	4	4
Sector Coupling	10	10	11	8	9	9	11	10	8	7
Software Provider	3	2	6	6	4	5	6	6	2	5
Technical Services	9	9	8	11	11	10	10	9	9	9
Technology Sales	14	16	17	17	17	15	15	16	15	16

Figure 4.27: Yearly ranking of the business model classes - 3514-Trade of electricity.

3512-Transmission of electricity

The section, transmission of electricity (see Figure 4.28), also accounted for approximately 2% of the total number of companies and includes: operation of transmission systems that convey the electricity from the generation facility to the distribution system [44]. The class, Prosumer, ranked consistently high amongst this group, rising 1 place into position 2 in 2011 and staying there until 2019. Gains were seen overall by the class, Energy Services, which rose 4 places to position 3 from 2010 to 2012, then after dropping 2 places in the rankings over the following 3 years, remained as the third most represented class from 2016 onward, and the classes, Sales Methods and Sector Coupling, both of which saw relatively steady increases in ranking from 2012 onward to rise by 3 places to 6 and 5 places to 8, respectively. The greatest losses were by the class, Conventional Production, which, after rising 2 places in 2011 to place 6, steadily declined throughout the remainder of the decade, ultimately ending up in place 11, the class, Technology Sales, which steadily dropped in rank from place 10 in 2010 to place 14 by 2019, and the class, Software Provider, which, while seeing relatively high levels of representation for most of the decade, ranking amongst the top 6 classes for a total of 7 years, also saw the greatest drop in ranking of 5 places, twice, in 2011 to place 7 and in 2019 to place 9.

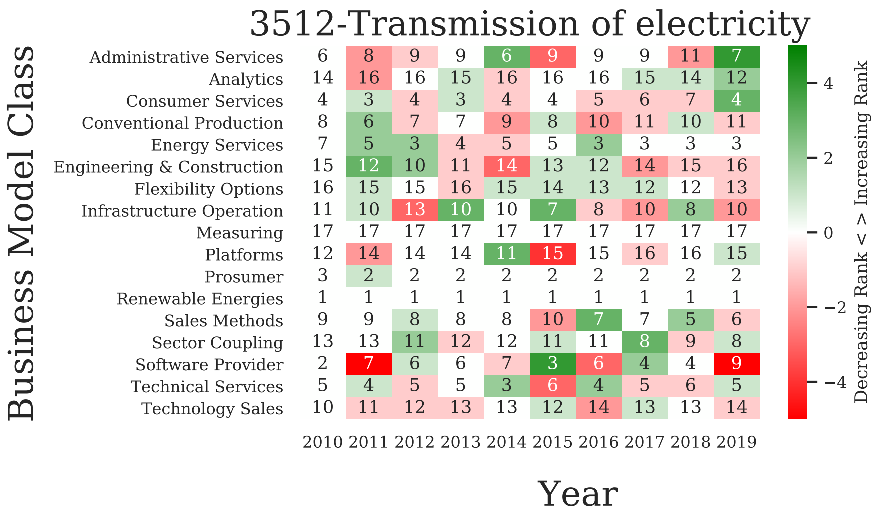


Figure 4.28: Yearly ranking of the business model classes - 3512-Transmission of electricity.

3520-Manufacture of gas; distribution of gaseous fuels through mains
This section (see Figure 4.29) accounted for around 1.4% of the sample of companies and includes: manufacture of gas and the distribution of natural or synthetic gas to the consumer through a system of mains; and gas marketers or brokers, which arrange the sale of natural gas over distribution systems operated by others [44]. The class, Conventional Production, was the most represented class in this group for the entire 10 year period. The classes that placed 2, 3 and 4 in the ranking changed intermittently between Renewable Energies, Consumer Services and Energy Services. The classes, Infrastructure Operation and Sales Methods, also ranked higher than their respective national averages and placed frequently within the top 6 ranked classes. The class, Software Provider, displayed relatively steady levels of growth, recovering from 2 slumps in 2013 and 2016, to gain 4 points overall, moving from place 10 in 2010 to place 6 in 2019 and the greatest loss overall was the class, Platforms, which saw an uncharacteristically high ranking in 2010 and 2011, being in places 9 and then 8, but in the end dropped a total of 8 places to place 17 in by 2018.

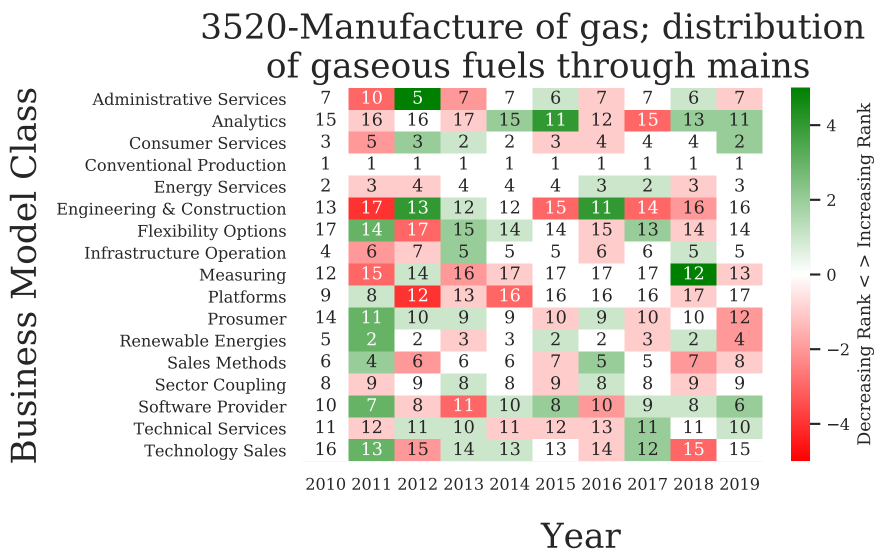
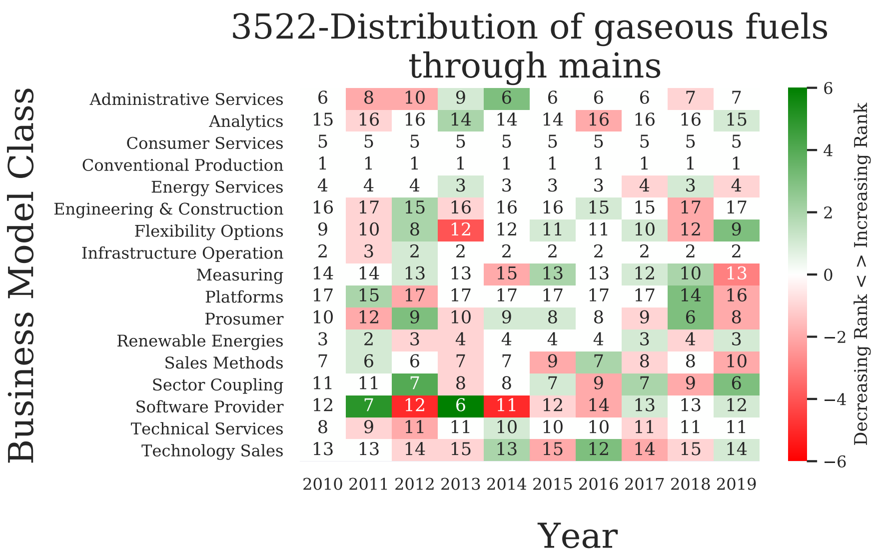


Figure 4.29: Yearly ranking of the business model classes - 3520-Manufacture of gas; distribution of gaseous fuels through mains.

3522-Distribution of gaseous fuels through mains
Companies making up this section (see Figure 4.30) of the NACE codes were not very numerous, making up just over 1% of the sample total. This section includes distribution and supply of gaseous fuels of all kinds through a system of mains and excludes (long-distance) transportation of gases by pipelines [44]. In this group the dominant classes were, Conventional Production, which was the most represented class for the entire time period, and Infrastructure Operation, which was the second most represented class for 9 years. The classes, Energy Services and Renewable Energies, shifted mostly between place 3 and 4 throughout the decade while the class, Consumer Services, was consistently the fifth ranked class. The most notable gain in ranking was by the class, Sector Coupling, which rose relatively steadily from place 11 in 2010 and 2011, to place 6 in 2019. The greatest losses in ranking in this group were by the classes, Sales Methods and Technical Services, which each moved 3 places down the rankings between 2010 and 2019, from place 7 to place 10 and from place 8 to place 11, respectively.



Business Model Class	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Administrative Services	6	8	10	9	6	6	6	6	7	7
Analytics	15	16	16	14	14	14	16	16	16	15
Consumer Services	5	5	5	5	5	5	5	5	5	5
Conventional Production	1	1	1	1	1	1	1	1	1	1
Energy Services	4	4	4	3	3	3	3	4	3	4
Engineering & Construction	16	17	15	16	16	16	15	15	17	17
Flexibility Options	9	10	8	12	12	11	11	10	12	9
Infrastructure Operation	2	3	2	2	2	2	2	2	2	2
Measuring	14	14	13	13	15	13	13	12	10	13
Platforms	17	15	17	17	17	17	17	17	14	16
Prosumer	10	12	9	10	9	8	8	9	6	8
Renewable Energies	3	2	3	4	4	4	4	3	4	3
Sales Methods	7	6	6	7	7	9	7	8	8	10
Sector Coupling	11	11	7	8	8	7	9	7	9	6
Software Provider	12	7	12	6	11	12	14	13	13	12
Technical Services	8	9	11	11	10	10	10	11	11	11
Technology Sales	13	13	14	15	13	15	12	14	15	14

Figure 4.30: Yearly ranking of the business model classes - 3522-Distribution of gaseous fuels through mains.

3523-Trade of gas through mains
Trade of gas through mains (see Figure 4.31) was least cited of all the NACE codes as being the primary activity, accounting for less than 0.5% the total sample of companies. This section includes: sale of gas to the user through mains; activities of gas brokers or agents that arrange the sale of gas over gas distribution systems operated by others; and commodity and transport capacity exchanges for gaseous fuels. Excluded from this section are: wholesale of gaseous fuels; retail sale of bottled gas; and direct selling of fuel [44]. Energy production methods, reflected in the classes, Conventional Production and Renewable Energies, again play a dominant role, being the first and second most represented classes from 2012 onward. The class, Administrative Services, increases in ranking from place 10 in 2010 to place 5 in 2014 and maintains a place in the top 5 ranking for the remainder of the decade. A higher than usual ranking by the class, Flexibility Options, can be observed, whereby this class shifts between places 7 and 10 in the rankings throughout the decade. Also of note is the class, Sales Methods, which starts the decade in 2010 as the second most represented class but gradually drops through the rankings to end up in place 10 by 2019.

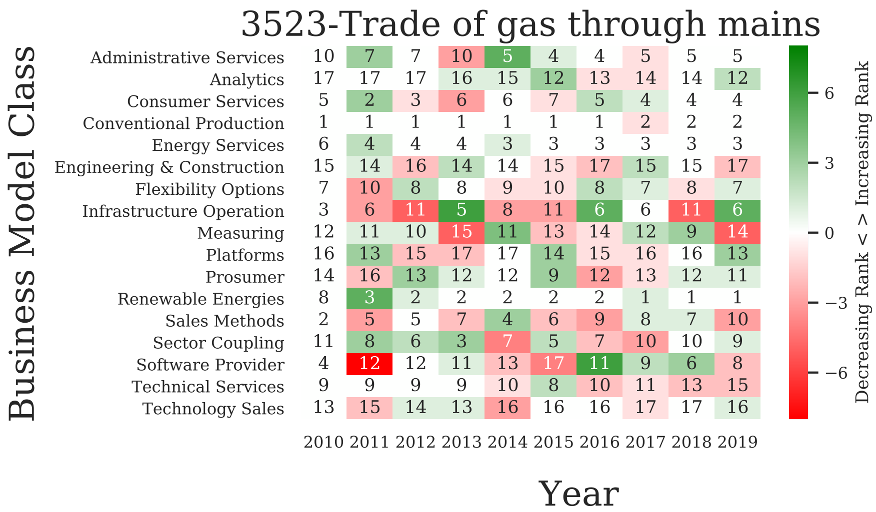


Figure 4.31: Yearly ranking of the business model classes - 3523-Trade of gas through mains.

The greatest increases and decreases in ranking by business model classes over the 10 year period in each of the groups of the NACE rev.2 codes are displayed in Table 4.2. Here the classes, Sector Coupling and Analytics, were the classes that most commonly had the highest increase in ranking, having the highest, or joint highest, increase in ranking in 5 and 4 of the 11 NACE code groups, respectively. The classes which most often appeared as having the greatest overall decrease in ranking from 2010 to 2019 were the classes, Technology Sales and Administrative Services, each featuring 3 times as the class with the greatest, or joint greatest, decrease in the overall ranking.

NACE rev.2 code	Greatest overall increase in rank Business model class	Places increased	Greatest overall decrease in rank Business model class	Places decreased
3511-Production of electricity	Software Provider, Analytics, Flexibility Options	4	Technology Sales	4
3500-Electricity, gas, steam and air conditioning supply	Sector Coupling	5	Administrative Services	3
3513-Distribution of electricity	Sector Coupling, Flexibility Options	2	Technology Sales	3
3530-Steam and air conditioning supply	Analytics	4	Administrative Services, Engineering & Construction	3
3521-Manufacture of gas	Software Provider, Analytics	3	Administrative Services	4
3510-Electric power generation, transmission and distribution	Flexibility Options	4	Technology Sales, Engineering & Construction	3
3514-Trade of electricity	Consumer Services, Sector Coupling	3	Infrastructure Operation	5
3512-Transmission of electricity	Sector Coupling	5	Software Provider	7
3520-Manufacture of gas; distribution of gaseous fuels through mains	Software Provider, Analytics	4	Platforms	8
3522-Distribution of gaseous fuels through mains	Sector Coupling	5	Sales Methods, Technical Services	3
3523-Trade of gas through mains	Renewable Energies	7	Sales Methods	8

Table 4.2: Greatest changes in overall ranking from 2010 to 2019 for each NACE rev.2 code

4.3 Co-occurrences of the Business Model Classes

The co-occurrence matrices shown in Figure 4.32 show which two business model classes appear together most frequently as the most represented class and second most represented class on websites. A darker shading represents a higher frequency of co-occurrence.

The co-occurrences of business model classes remained quite consistent over the decade with the majority of these being with Renewable Energies as the most represented class. It appeared most frequently together with the Prosumer class and also with the classes Technical Services, Energy Services and Conventional Production. From 2016 onward the class Software Provider starts to appear more frequently in conjunction with Renewable Energies. Other frequent co-occurrences are the class Prosumer appearing as the most represented class together with Renewable Energies as the second most represented class, and also the co-occurrences Conventional Production with Energy Services, Conventional Production with Consumer Services, and Energy Services with Sector Coupling. The classes Administrative Services and Consumer Services also commonly appeared together in both arrangements of order.

An alternative means of visualisation of the business model class co-occurrences can be found in Section .5 of the Annex in the form of network graphs (Figure .30). In these graphs each node represents a business model class and the size of each node represents how many of the other classes it co-occurred with as the most represented class. The thickness of the lines connecting each node indicate the total number of co-occurrences featuring both classes and the size of the arrow head indicates which of the classes appeared more frequently as the most represented of the two. In addition the top 20 co-occurrences for each year can be found in tabular form in Section .4 of the Annex.

The following chapter concludes this thesis with a brief summary and suggestions for further study.

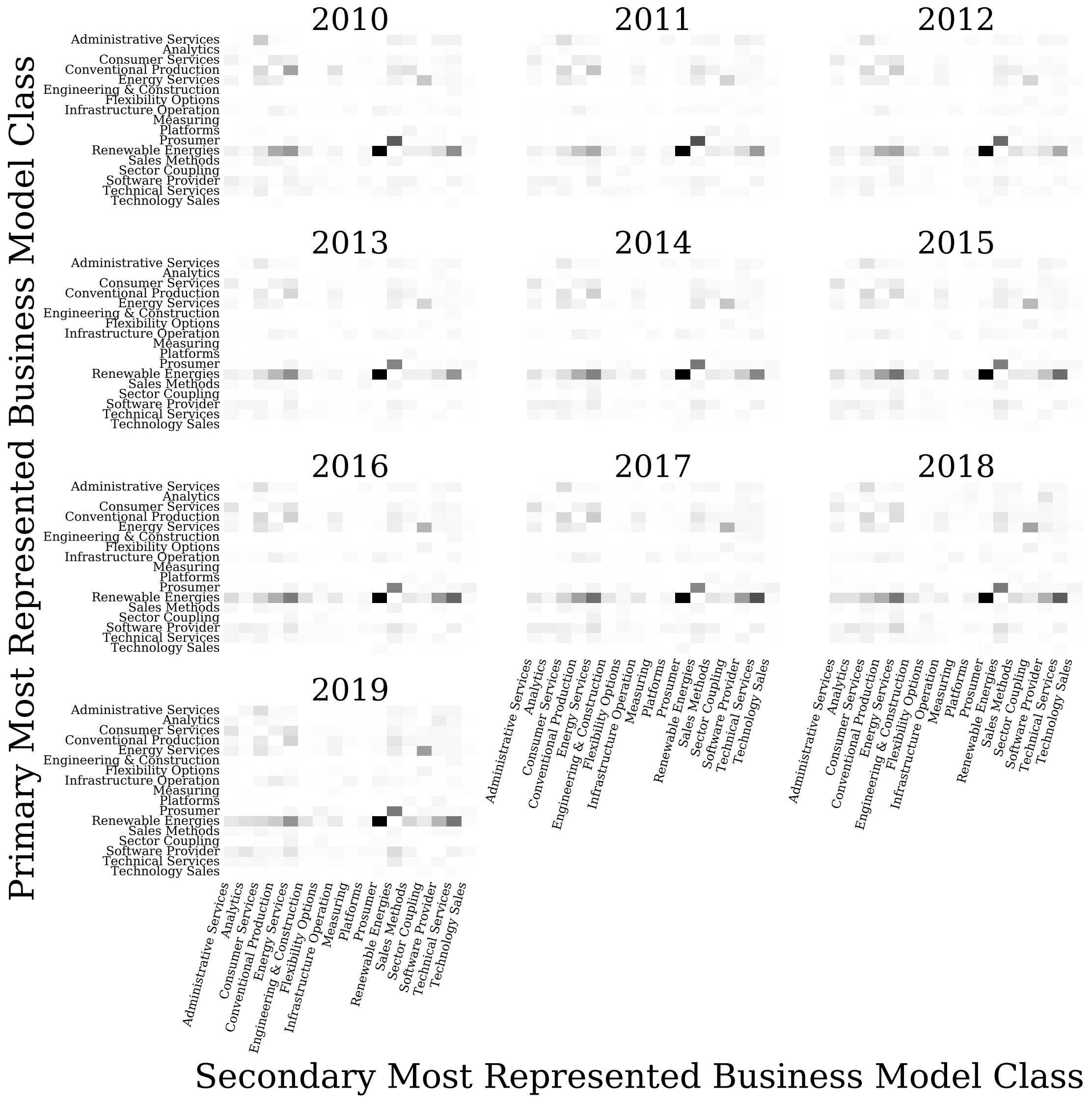


Figure 4.32: Co-occurrence matrices of the business model classes.

5 Conclusion

This final chapter presents a summary of the thesis and proposes some potential areas for future work.

5.1 Summary

The main aim of this research is to investigate the extent to which the business model classes of the German energy sector, as defined by Giehl et al., are represented in the text on websites of the companies operating in the energy sector and to what extent this has changed in the decade from 2010 to 2019. The results of this study suggest that the business model class, Renewable Energies, is represented in the language used by companies on their websites to a much greater extent then any of the other classes and this has been the case since at least 2010. The decade saw a decline in the use of language relating to Conventional Production, reflecting the changing mix in the sources of energy used in Germany. There appears also to be a trend amongst companies to use language relating to the provision of services with business model classes relating to service provision consistently ranking amongst the top 10 most represented classes on average and frequently also within the top 5. An increase in the use of language relating to the business model class, Software Provider, can be observed from 2014 onward but in general the mean levels of representation of the various business model classes in Germany remained largely stable.

On a federal state level it can be seen that in the more economically developed states of former West Germany: Bavaria, Baden-Württemberg, Lower Saxony and North Rhine-Westphalia, there is considerable stability in the level of representation of the business model classes. This is however not the case for all of the former West German states as can be seen most clearly in the case of Saarland, where much variation can be seen throughout the decade. Higher levels of dynamism tend also to be seen in the states of former East Germany and in the city states of Berlin, Bremen and Hamburg. The business model class that most commonly displayed the highest increase in ranking over the observed period was the class, Software Provider, appearing as the class with the highest, or joint highest, overall increase in ranking in 50% of the federal states, rising by an average of 6 places in each state, while the class that most often displayed the greatest decrease in ranking was the class, Technology Sales, appearing as the class with the greatest decrease in ranking in 44% of the federal states, falling on average by 5 places in each state.

Looking at the mean levels of representation based on the primary activity of the companies in accordance with the NACE standards, it can be seen that there is often less dominance by the use of language relating to the business model class, Renewable Energies. The extent to which language relating to the various classes features on websites tends often to reflect the particular NACE code, for example, companies whose primary activity has to do with energy distribution tend more often to use language related to the class, Infrastructure Operation, and companies whose primary activity has to do with trade have a tendency to use language related to the class, Sales Methods, higher than the national average. Amongst these groups the business model class that most frequently displayed the greatest increase in ranking from 2010 to 2019 was the class, Sector Coupling, which appeared as the class with the highest, or joint highest, increase in ranking in 46% of the groups, with an average increase of 4 places per group. The classes that most often displayed the greatest decrease in ranking were the class, Technology Sales, and the class, Administrative Services. These each appeared as the classes with the greatest decrease in ranking in 27% of the groups, with an average drop of 3 places per group.

This study has shown that the text used by companies on their websites can be a useful source of information that can provide valuable insight into the energy sector and show to what extent particular areas are represented and how companies attempt to portray themselves to the outside world. While companies may be involved in other activities that they find less necessary to publicise on their websites, the information found on websites can help to gauge the overall mood of the market and how it adapts and corresponds to changing trends in society as a whole. This study also shows how the method of thesaurus based text categorisation can be used to categorise documents although this method is not without limitations. While care was taken to compile a thesaurus that reflected to as great an extent as possible the various business model classes that make up the German energy sector, the collections of terminology were by no means exhaustive and although it would be possible to compile a larger, more comprehensive thesaurus, there would be extra costs in terms of the necessary computational power required or time needed to execute the categorisation process. The ambiguity of some of the business model classes and the boundaries between them, while accurately representing the interwoven nature of the energy market, complicated the process of compiling a thesaurus with distinct sets of terminology and this method of text categorisation may be employed more effectively with more specific, clearly defined categories.

5.2 Outlook

There is much potential for applying similar methodology in future work to extract knowledge from website text data. A thesaurus based confirmatory approach may be used in order to explore other areas and verify their level of representation on websites. In this case it may prove more effective to focus on specific areas, for example, the level of representation of certain technologies could be accurately gauged, as a comprehensive and exhaustive thesaurus relating to specific technologies, such as electric vehicles or photovoltaic technologies, could be compiled with greater ease and accuracy than a thesaurus of more ambiguous topics. In addition, there may be information contained within the text data that is not so intuitive or obvious to look for. In order to extract such knowledge it may be interesting to apply some exploratory approaches of text mining to the data. This would require considerable continued preprocessing of the data to ensure that it is adequately clean but would enable the application of topic modelling methods such as latent dirichlet allocation, which may deliver a greater level of insight and expand understanding of the German energy market. Other work may indeed chose to take a closer look at the business model classes used in this study and attempt to identify possible reasons for the variation in their levels of representation throughout the decade, possibly considering different strategies, for example, policy making, pursued by the individual states that make up Germany, or looking more closely at how the specific activities carried out by companies may influence the levels of representation of the business model classes.

List of Acronyms

API	Application Programming Interface
ASCII	American Standard Code for Information Interchange
BoW	Bag-of-Words
BMC	Business Model Class
EC	European Commission
EU	European Union
CCS	Carbon Capture and Storage
CSV	Categorisation Status Value
CPU	Central Processing Unit
DSM	Demand Side Management
GB	Gigabyte
GW	Gigawatt
HTML	Hypertext Markup Language
IoT	Internet of Things
KDD	Knowledge Discovery in Databases
LDA	Latent Dirichlet Allocation
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne
NAICS	North American Industry Classification System
NLTK	Natural Language Toolkit
NLP	Natural Language Processing
PDF	Portable Document Format
VPP	Virtual Power Plant
PHP	Hypertext Preprocessor, originally, Personal Home Page
PV	Photovoltaic
URL	Uniform Resource Locator
XML	Extensible Markup Language

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Annex

.1 Code Used in the Completion of this Thesis

All of the code used in the completion if this thesis can be found at `https://github.com/RorymcB/A-Text-Mining-Based-Assessment-of-Business-Fields-within-the-German-Energy-Market`. In addition the full business model thesaurus, the stemmed business model thesaurus and the normalised numerical representation of the business model classes have been stored here also.

.2 Sources Used in the Creation of the Business Model Thesaurus

Administrative Services
[62] [63] [64] [65] [66] [67] [68] [69] [70] [71] [72] [73] [74] [75] [76] [77] [78]
Analytics
[79] [80] [81] [82] [83] [84] [85] [86] [87]
Consumer Services
[88] [89] [90] [91] [92] [93] [94] [95] [96] [97] [98] [99] [100] [101] [102] [103] [104]
Conventional Production
[105] [106] [107] [108] [109] [110] [111] [112] [113] [114] [115] [116]
Engineering & Construction
[117] [118] [119] [120] [121] [122] [123] [124] [125]
Energy Services
[126] [127] [128] [129] [130] [131] [132] [133] [134] [135] [136] [137] [138] [139] [140] [141]
Flexibility Options
[142] [143] [144] [145] [146] [147] [148] [149] [150] [151] [152] [153] [154] [155]
Infrastructure Operation
[156] [157] [158] [159] [160] [161] [162] [163] [164] [165] [166]
Measuring
[167] [168] [169] [170] [171] [172] [173] [174] [175]
Platforms
[176] [177] [178] [179] [180] [181] [182] [183] [184] [185] [186] [187] [188] [189] [190]
Prosumer
[191] [192] [193] [194] [195] [196] [197] [198] [199] [200] [201] [202] [203]
Renewable Energies
[204] [205] [206] [207] [208] [209] [210]
Sales Methods
[211] [212] [213] [214] [215] [216] [217] [218] [219] [220] [221] [222] [223] [224] [225]
Sector Coupling
[226] [227] [228] [229] [230] [231] [232]
Software Provider
[233] [234] [235] [236] [237] [238] [239] [240] [241] [242] [243] [244] [245]
Technical Services
[246] [247] [248] [249] [250] [251] [252] [253] [254] [255] [256]
Technology Sales
[257] [258] [259] [260] [261] [262] [263]

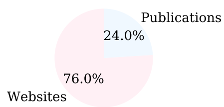

Figure .1: Origins of the sources.

.3 Line Plots

.3.1 Germany

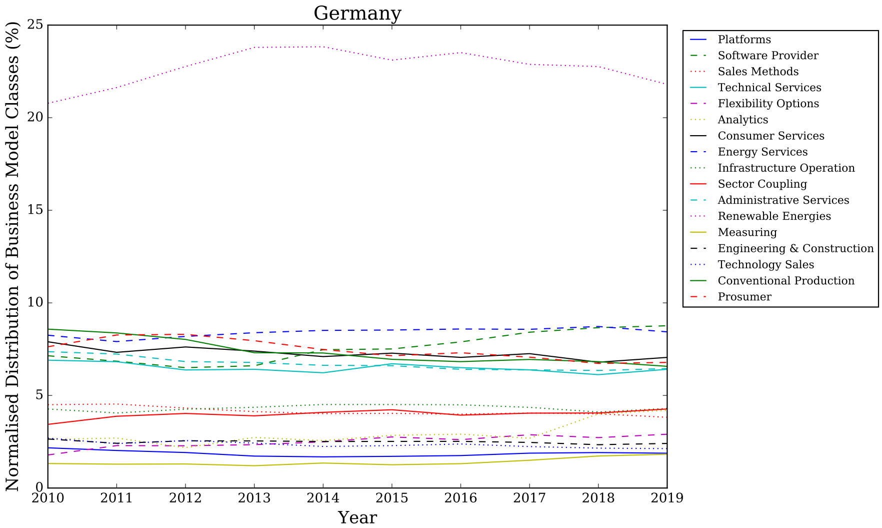

Figure .2: Average yearly representation of the business model classes - Germany.

.3.2 German Federal States

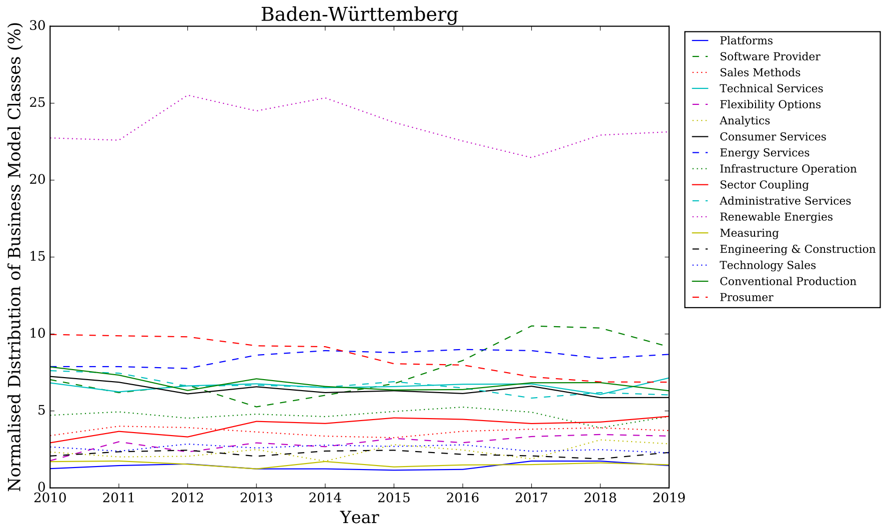

Figure .3: Average yearly representation of the business model classes - Baden-Württemberg.

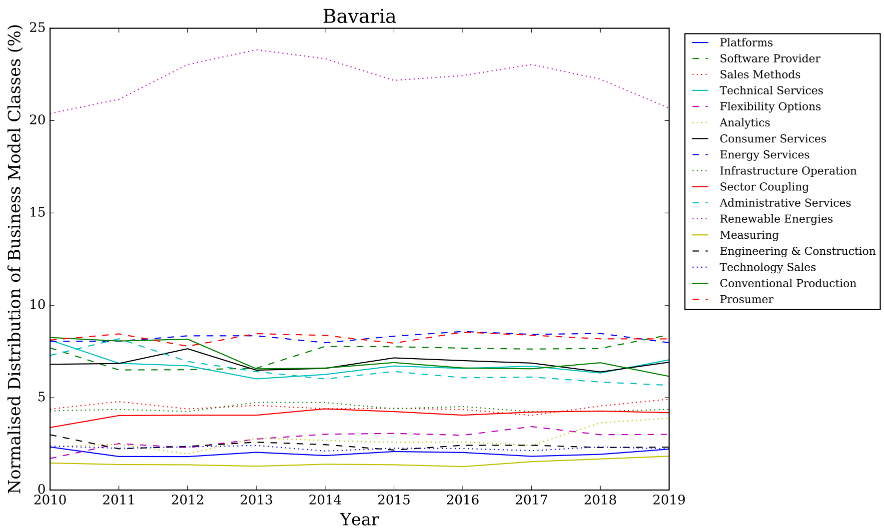

Figure .4: Average yearly representation of the business model classes - Bavaria.

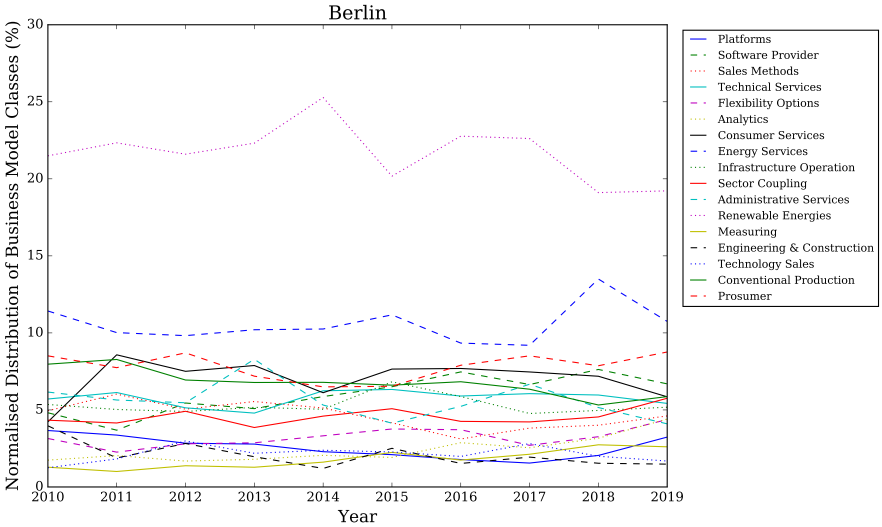

Figure .5: Average yearly representation of the business model classes - Berlin.

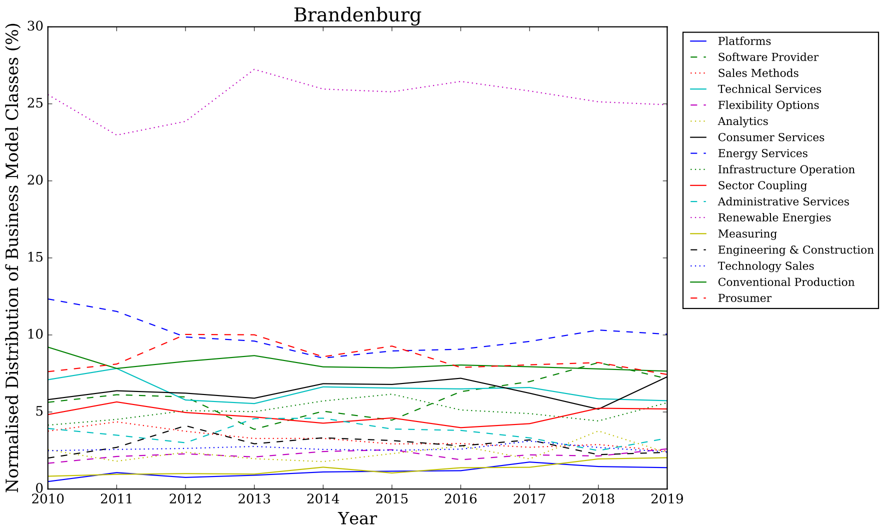

Figure .6: Average yearly representation of the business model classes - Brandenburg.

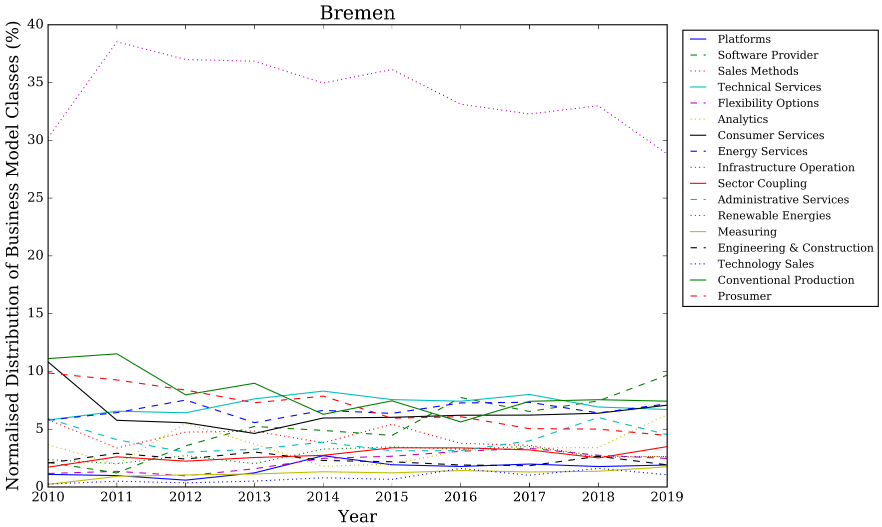

Figure .7: Average yearly representation of the business model classes - Bremen.

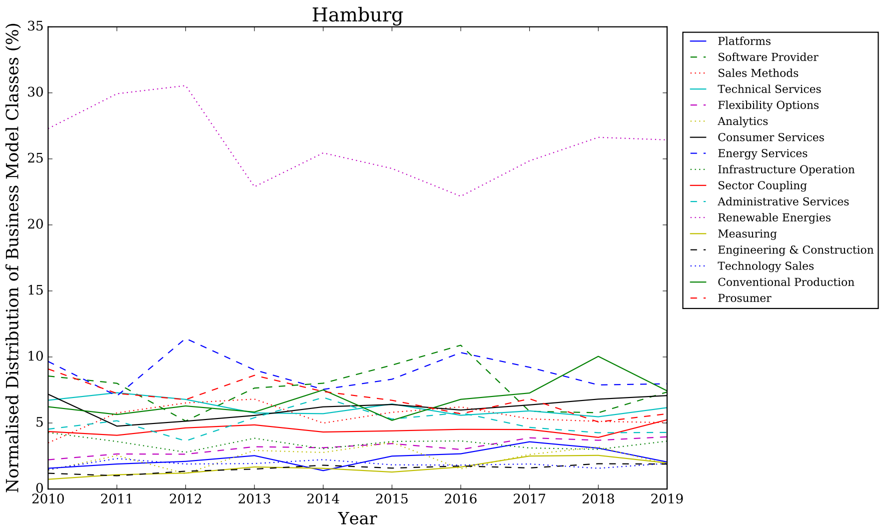

Figure .8: Average yearly representation of the business model classes - Hamburg.

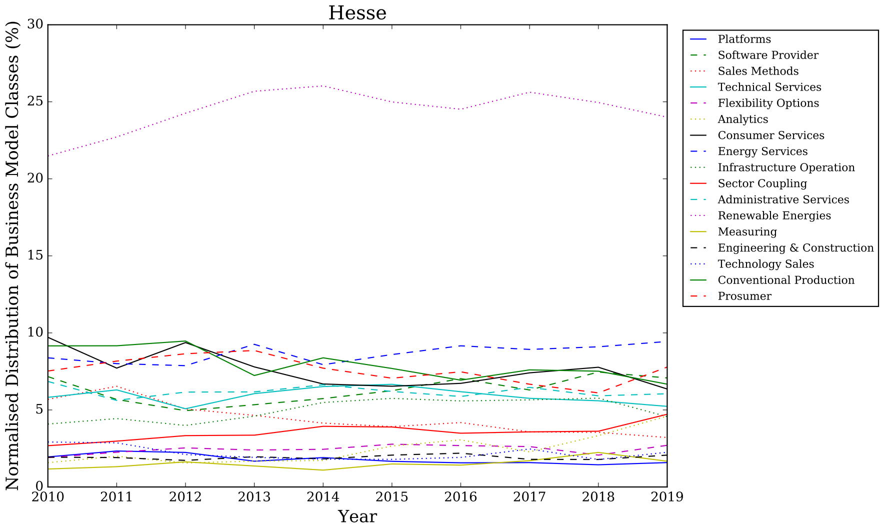

Figure .9: Average yearly representation of the business model classes - Hesse.

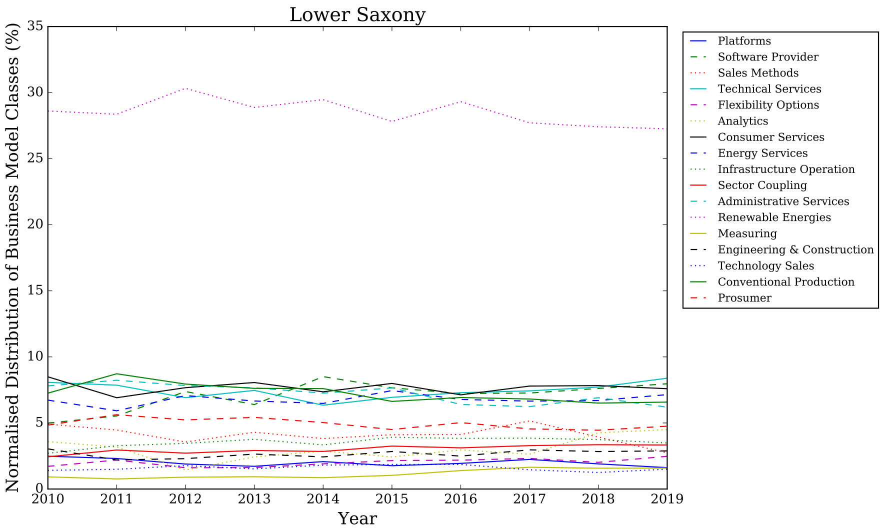

Figure .10: Average yearly representation of the business model classes - Lower Saxony.

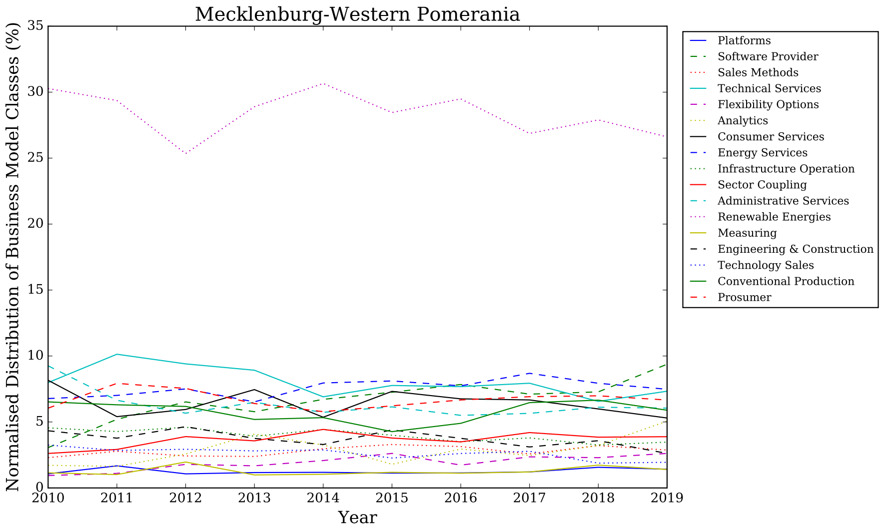

Figure .11: Average yearly representation of the business model classes - Mecklenburg-Western Pomerania.

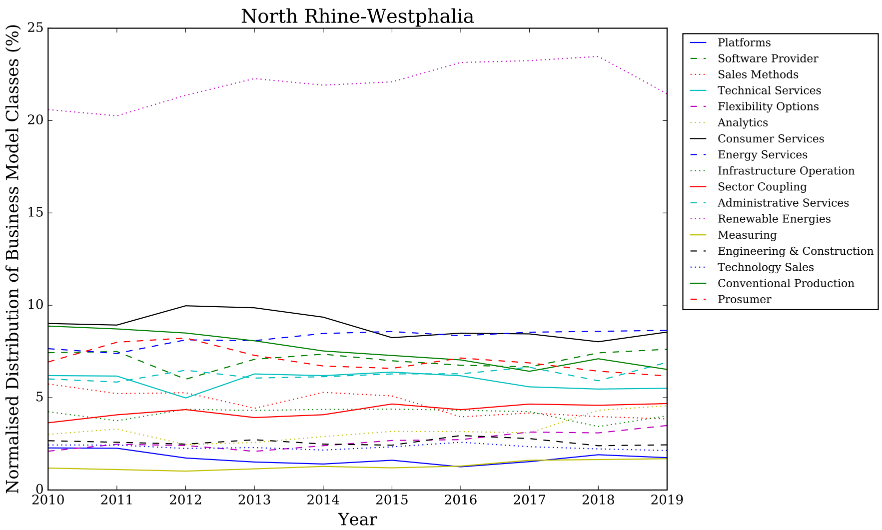

Figure .12: Average yearly representation of the business model classes - North Rhine-Westphalia.

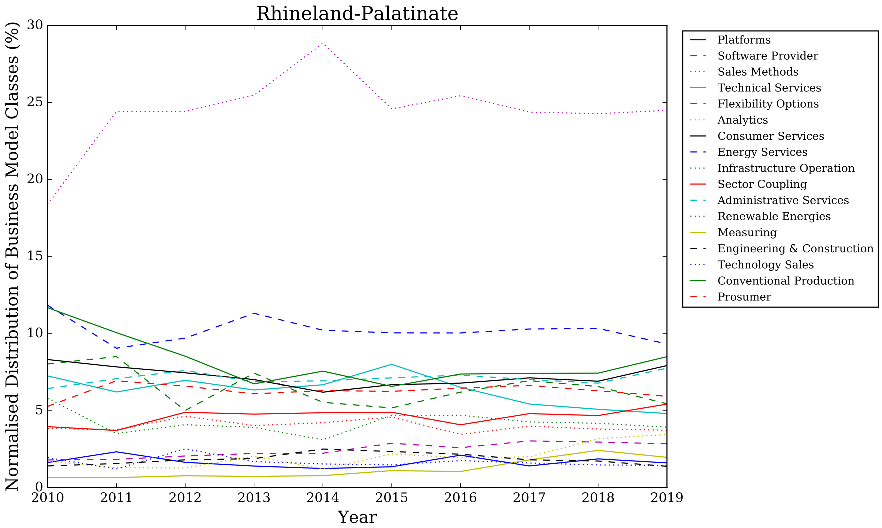

Figure .13: Average yearly representation of the business model classes - Rhineland-Palatinate.

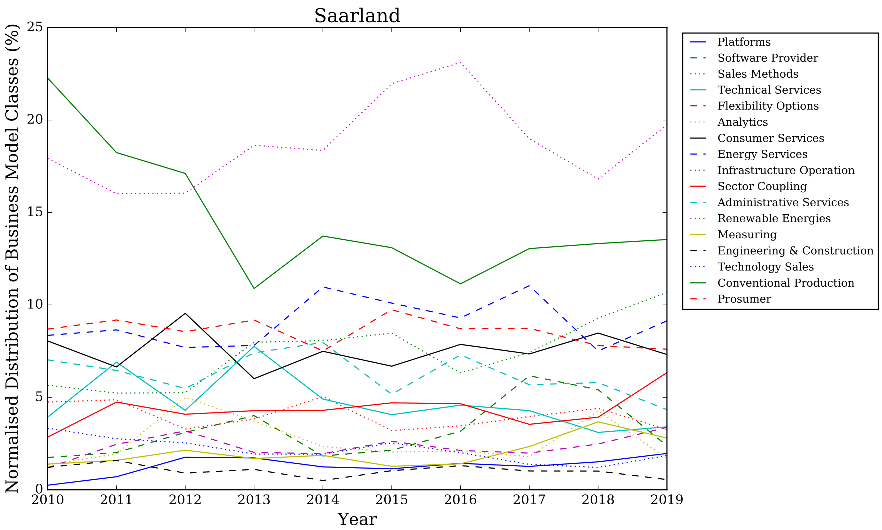

Figure .14: Average yearly representation of the business model classes - Saarland.

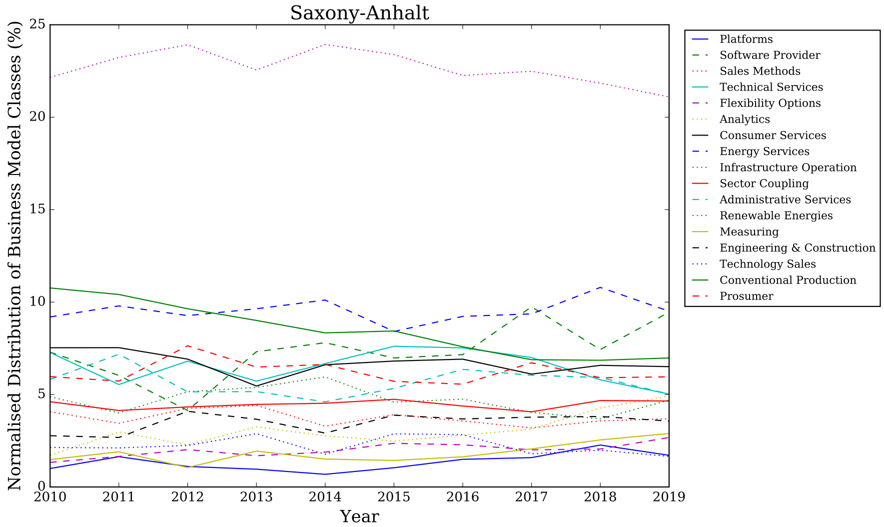

Figure .15: Average yearly representation of the business model classes - Saxony-Anhalt.

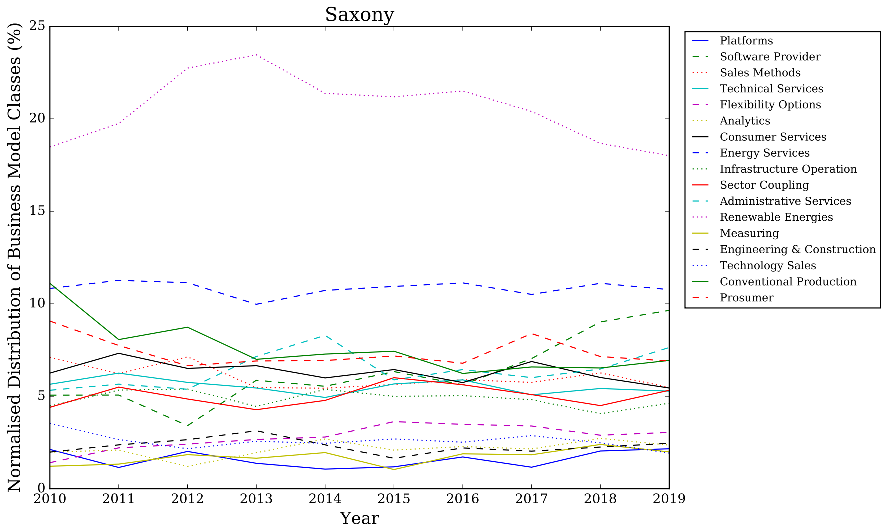

Figure .16: Average yearly representation of the business model classes - Saxony.

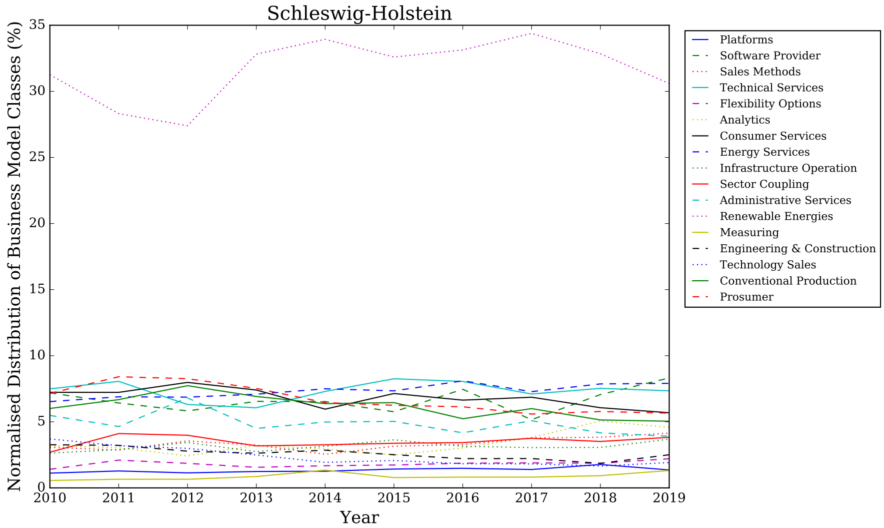

Figure .17: Average yearly representation of the business model classes - Schleswig-Holstein.

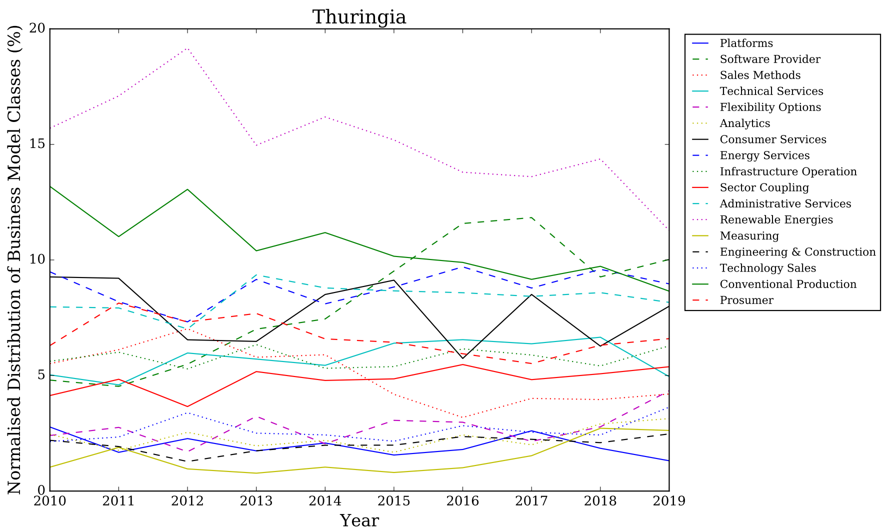

Figure .18: Average yearly representation of the business model classes - Thuringia.

.3.3 NACE rev.2 Primary Codes

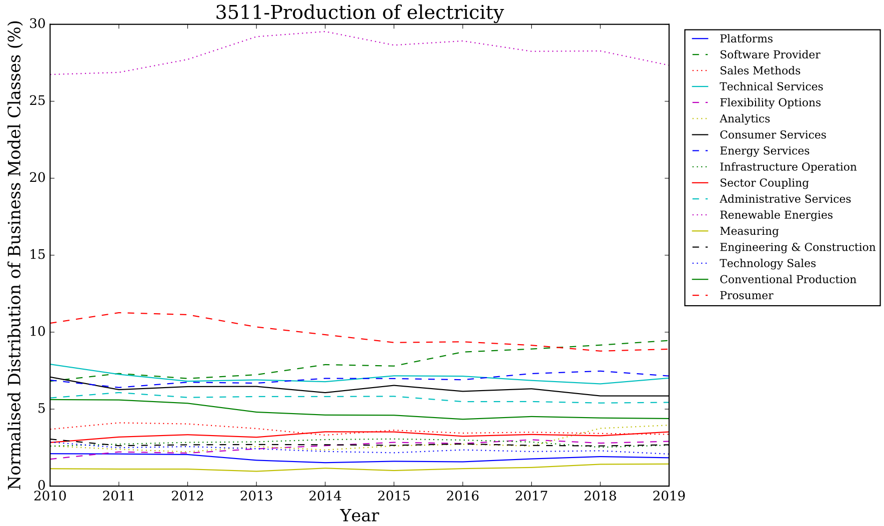

Figure .19: Average yearly representation of the business model classes - 3511-Production of electricity.

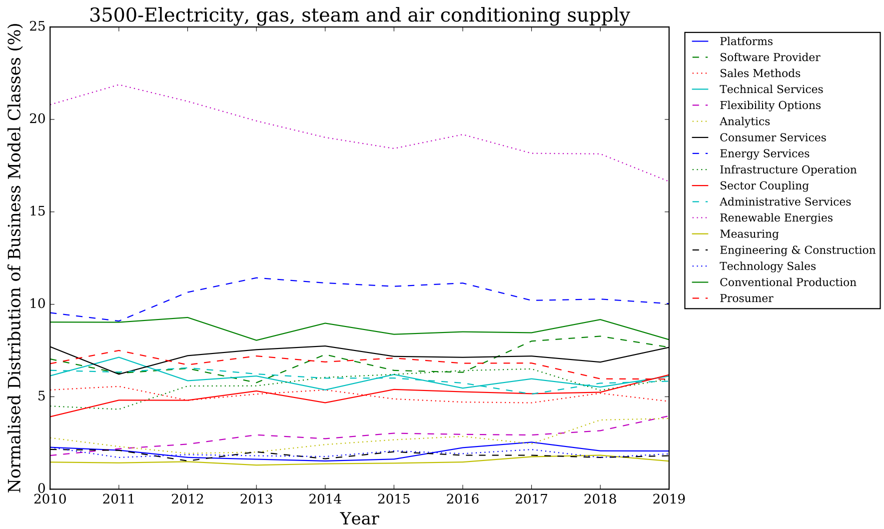

Figure .20: Average yearly representation of the business model classes - 3500-Electricity, gas, steam and air conditioning supply.

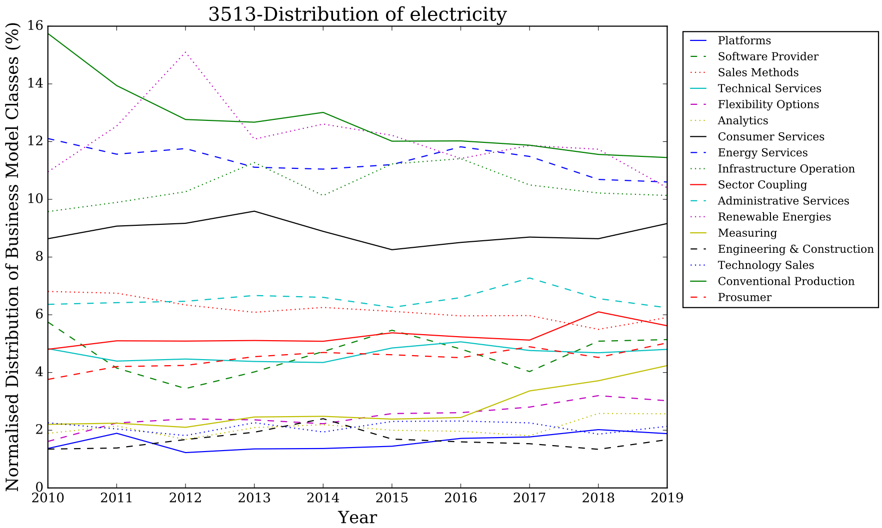

Figure .21: Average yearly representation of the business model classes - 3513-Distribution of electricity.

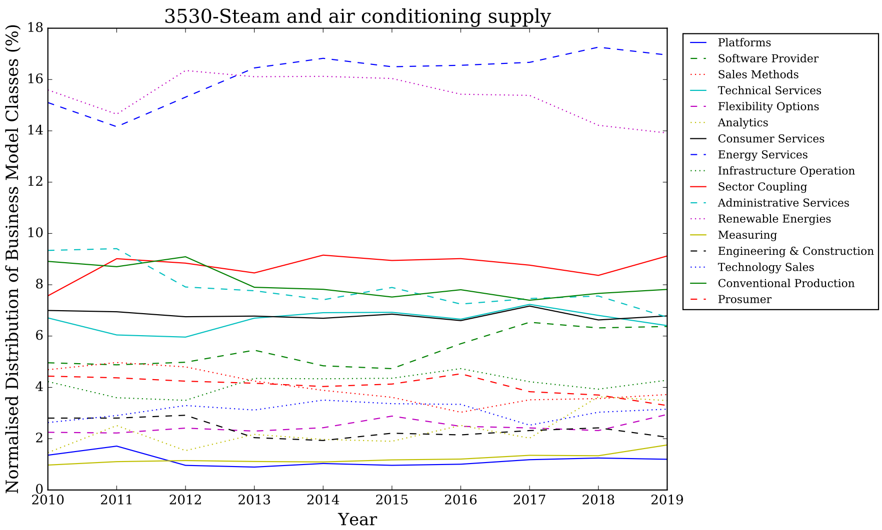

Figure .22: Average yearly representation of the business model classes - 3530-Steam and air conditioning supply.

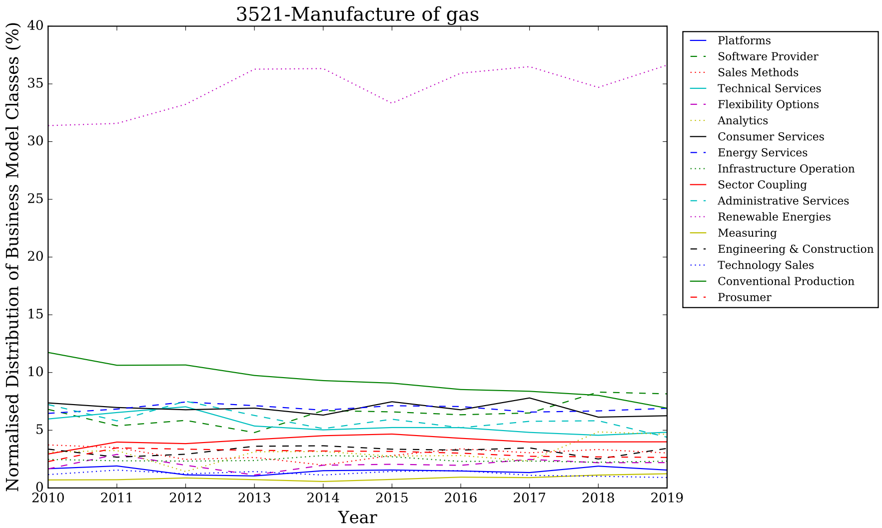

Figure .23: Average yearly representation of the business model classes - 3521-Manufacture of gas.

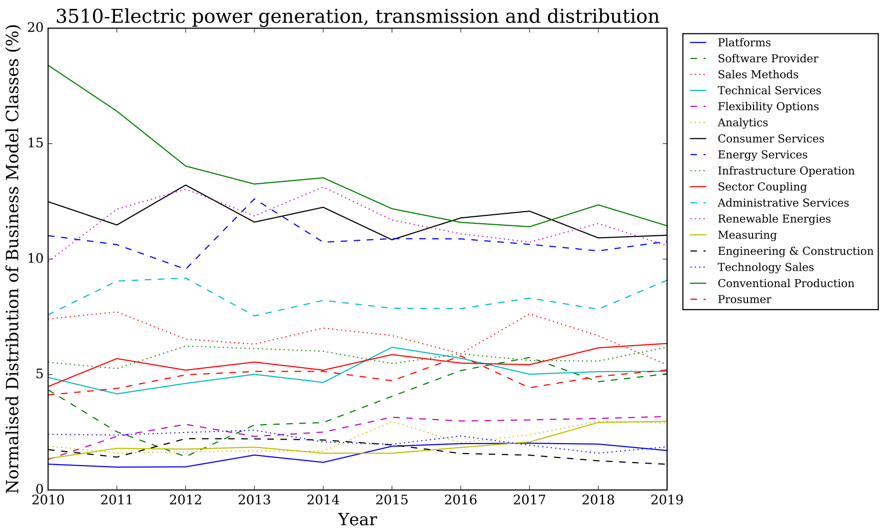

Figure .24: Average yearly representation of the business model classes - 3510-Electric power generation, transmission and distribution.

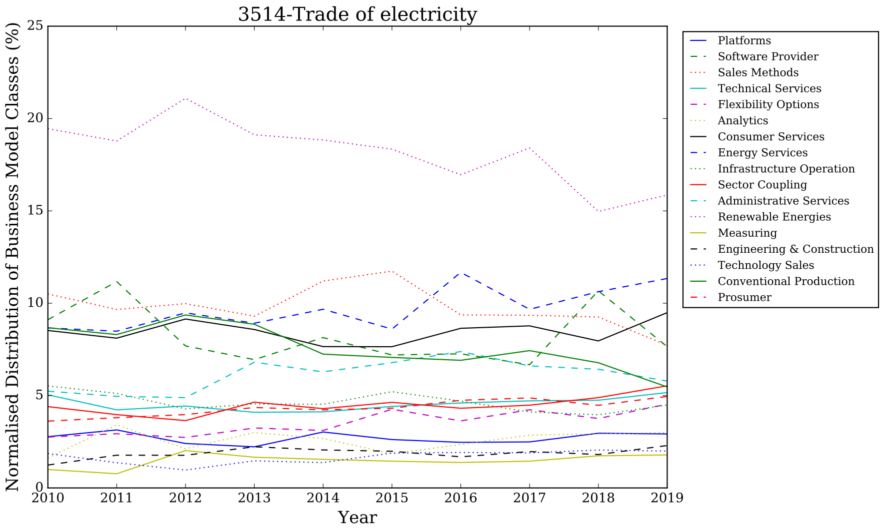

Figure .25: Average yearly representation of the business model classes - 3514-Trade of electricity.

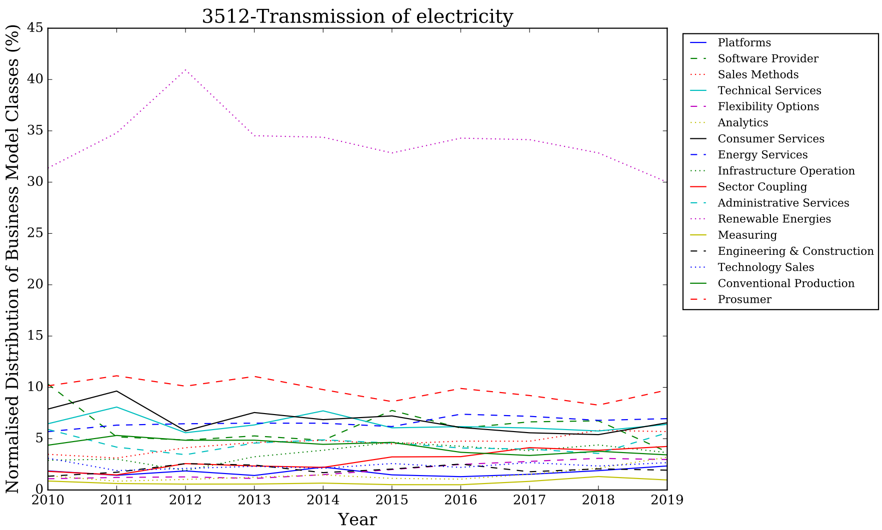

Figure .26: Average yearly representation of the business model classes - 3512-Transmission of electricity.

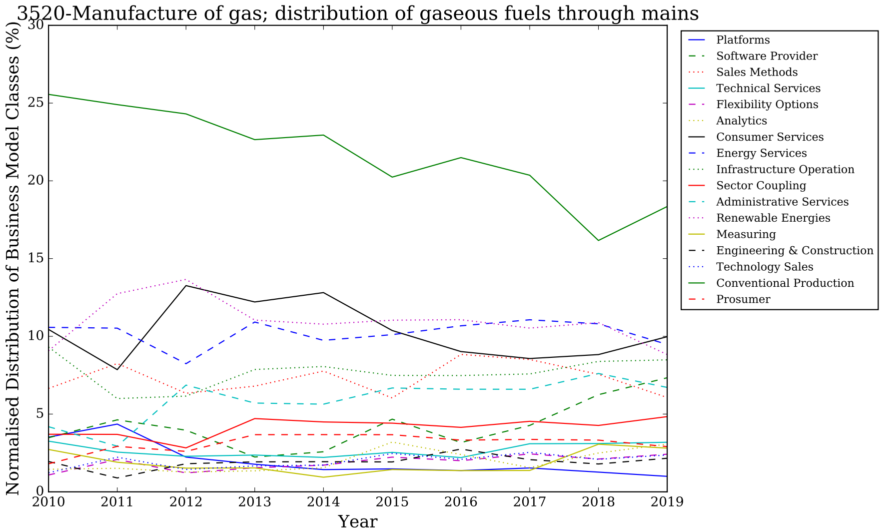

Figure .27: Average yearly representation of the business model classes - 3520-Manufacture of gas; distribution of gaseous fuels through mains.

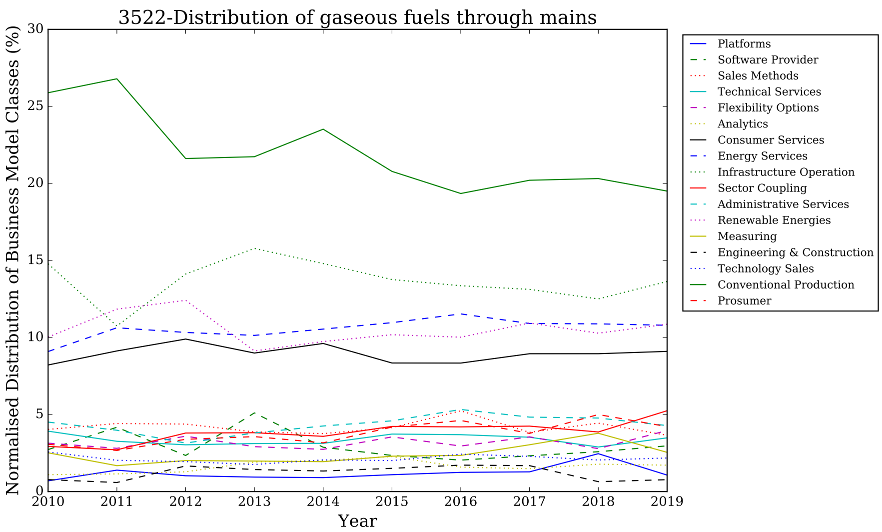

Figure .28: Average yearly representation of the business model classes - 3522-Distribution of gaseous fuels through mains.

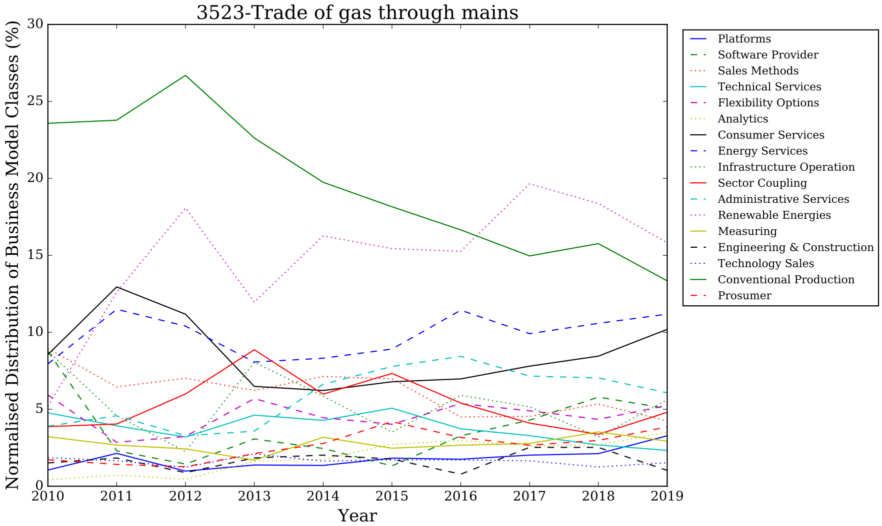

Figure .29: Average yearly representation of the business model classes - 3523-Trade of gas through mains.

.4 Top 20 Business Model Class Co-occurrences for each Year

2010		
Co-occurrence	**Total amount**	**% of total**
Renewable Energies=>Prosumer	143	7.69
Prosumer=>Renewable Energies	102	5.48
Renewable Energies=>Technical Services	76	4.09
Renewable Energies=>Energy Services	71	3.82
Conventional Production=>Energy Services	66	3.55
Renewable Energies=>Conventional Production	63	3.39
Energy Services=>Sector Coupling	47	2.53
Administrative Services=>Consumer Services	45	2.42
Conventional Production=>Consumer Services	35	1.88
Renewable Energies=>Software Provider	32	1.72
Conventional Production=>Infrastructure Operation	29	1.56
Conventional Production=>Sales Methods	29	1.56
Energy Services=>Consumer Services	25	1.34
Consumer Services=>Conventional Production	25	1.34
Conventional Production=>Renewable Energies	25	1.34
Renewable Energies=>Consumer Services	24	1.29
Renewable Energies=>Engineering & Construction	20	1.08
Software Provider=>Administrative Services	20	1.08
Technical Services=>Consumer Services	20	1.08
Renewable Energies=>Sales Methods	20	1.08

Table .1: Co-occurrences of business model classes (2010).

2011		
Co-occurrence	**Total amount**	**% of total**
Renewable Energies=>Prosumer	177	8.34
Prosumer=>Renewable Energies	133	6.27
Renewable Energies=>Technical Services	86	4.05
Renewable Energies=>Energy Services	77	3.63
Conventional Production=>Energy Services	62	2.92
Renewable Energies=>Conventional Production	61	2.87
Energy Services=>Sector Coupling	49	2.31
Conventional Production=>Consumer Services	43	2.03
Renewable Energies=>Software Provider	41	1.93
Administrative Services=>Consumer Services	40	1.89
Conventional Production=>Renewable Energies	37	1.74
Renewable Energies=>Consumer Services	32	1.51
Energy Services=>Consumer Services	29	1.37
Renewable Energies=>Sales Methods	27	1.27
Consumer Services=>Conventional Production	26	1.23
Software Provider=>Energy Services	25	1.18
Energy Services=>Renewable Energies	25	1.18
Consumer Services=>Administrative Services	24	1.13
Administrative Services=>Software Provider	24	1.13
Consumer Services=>Energy Services	22	1.04
2012		
Co-occurrence	**Total amount**	**% of total**
Renewable Energies=>Prosumer	191	8.52
Prosumer=>Renewable Energies	125	5.57
Renewable Energies=>Energy Services	88	3.92
Renewable Energies=>Technical Services	83	3.7
Renewable Energies=>Conventional Production	80	3.57
Conventional Production=>Energy Services	58	2.59
Energy Services=>Sector Coupling	50	2.23
Conventional Production=>Consumer Services	46	2.05
Administrative Services=>Consumer Services	39	1.74
Renewable Energies=>Software Provider	39	1.74
Renewable Energies=>Sales Methods	39	1.74
Renewable Energies=>Consumer Services	34	1.52
Consumer Services=>Energy Services	33	1.47
Consumer Services=>Administrative Services	29	1.29
Renewable Energies=>Engineering & Construction	29	1.29
Conventional Production=>Renewable Energies	29	1.29
Consumer Services=>Conventional Production	28	1.25
Energy Services=>Conventional Production	27	1.2
Conventional Production=>Sales Methods	27	1.2
Renewable Energies=>Administrative Services	25	1.11

Table .2: Co-occurrences of business model classes (2011 - 2012).

2013

Co-occurrence	Total amount	% of total
Renewable Energies=>Prosumer	292	9.01
Prosumer=>Renewable Energies	166	5.12
Renewable Energies=>Energy Services	154	4.75
Renewable Energies=>Technical Services	148	4.57
Renewable Energies=>Conventional Production	113	3.49
Energy Services=>Sector Coupling	81	2.5
Conventional Production=>Energy Services	77	2.38
Renewable Energies=>Software Provider	67	2.07
Renewable Energies=>Consumer Services	60	1.85
Consumer Services=>Energy Services	49	1.51
Administrative Services=>Consumer Services	49	1.51
Renewable Energies=>Engineering & Construction	48	1.48
Conventional Production=>Consumer Services	47	1.45
Conventional Production=>Renewable Energies	42	1.3
Consumer Services=>Administrative Services	41	1.26
Renewable Energies=>Sales Methods	38	1.17
Energy Services=>Consumer Services	37	1.14
Renewable Energies=>Administrative Services	36	1.11
Software Provider=>Energy Services	36	1.11
Renewable Energies=>Sector Coupling	36	1.11

2014

Co-occurrence	Total amount	% of total
Renewable Energies=>Prosumer	244	7.89
Prosumer=>Renewable Energies	148	4.79
Renewable Energies=>Energy Services	141	4.56
Renewable Energies=>Technical Services	137	4.43
Renewable Energies=>Conventional Production	104	3.36
Energy Services=>Sector Coupling	82	2.65
Renewable Energies=>Software Provider	76	2.46
Conventional Production=>Energy Services	71	2.3
Renewable Energies=>Consumer Services	54	1.75
Renewable Energies=>Administrative Services	48	1.55
Conventional Production=>Consumer Services	46	1.49
Consumer Services=>Administrative Services	43	1.39
Energy Services=>Renewable Energies	43	1.39
Energy Services=>Consumer Services	42	1.36
Renewable Energies=>Engineering & Construction	42	1.36
Administrative Services=>Consumer Services	40	1.29
Consumer Services=>Energy Services	38	1.23
Software Provider=>Renewable Energies	38	1.23
Renewable Energies=>Sales Methods	38	1.23
Software Provider=>Energy Services	35	1.13

Table .3: Co-occurrences of business model classes (2013 - 2014).

2015		
Co-occurrence	**Total amount**	**% of total**
Renewable Energies=>Prosumer	239	7.4
Renewable Energies=>Technical Services	155	4.8
Renewable Energies=>Energy Services	149	4.61
Prosumer=>Renewable Energies	139	4.3
Renewable Energies=>Conventional Production	111	3.44
Energy Services=>Sector Coupling	93	2.88
Renewable Energies=>Software Provider	84	2.6
Conventional Production=>Consumer Services	60	1.86
Conventional Production=>Energy Services	59	1.83
Renewable Energies=>Administrative Services	52	1.61
Consumer Services=>Administrative Services	46	1.42
Renewable Energies=>Consumer Services	46	1.42
Administrative Services=>Consumer Services	45	1.39
Renewable Energies=>Engineering & Construction	44	1.36
Renewable Energies=>Infrastructure Operation	43	1.33
Software Provider=>Renewable Energies	42	1.3
Renewable Energies=>Sales Methods	40	1.24
Energy Services=>Consumer Services	40	1.24
Consumer Services=>Energy Services	37	1.15
Renewable Energies=>Sector Coupling	37	1.15
2016		
Co-occurrence	**Total amount**	**% of total**
Renewable Energies=>Prosumer	259	7.07
Renewable Energies=>Technical Services	174	4.75
Renewable Energies=>Energy Services	154	4.2
Prosumer=>Renewable Energies	149	4.07
Renewable Energies=>Software Provider	127	3.47
Renewable Energies=>Conventional Production	110	3.0
Energy Services=>Sector Coupling	106	2.89
Conventional Production=>Energy Services	74	2.02
Renewable Energies=>Consumer Services	66	1.8
Conventional Production=>Consumer Services	65	1.77
Renewable Energies=>Administrative Services	62	1.69
Renewable Energies=>Engineering & Construction	56	1.53
Administrative Services=>Consumer Services	55	1.5
Energy Services=>Consumer Services	54	1.47
Consumer Services=>Administrative Services	51	1.39
Consumer Services=>Energy Services	49	1.34
Software Provider=>Renewable Energies	47	1.28
Renewable Energies=>Sales Methods	45	1.23
Software Provider=>Energy Services	44	1.2
Renewable Energies=>Infrastructure Operation	44	1.2

Table .4: Co-occurrences of business model classes (2015 - 2016).

2017		
Co-occurrence	**Total amount**	**% of total**
Renewable Energies=>Prosumer	222	6.71
Renewable Energies=>Technical Services	168	5.08
Renewable Energies=>Energy Services	143	4.32
Prosumer=>Renewable Energies	124	3.75
Renewable Energies=>Software Provider	107	3.23
Renewable Energies=>Conventional Production	104	3.14
Energy Services=>Sector Coupling	88	2.66
Conventional Production=>Energy Services	69	2.08
Renewable Energies=>Consumer Services	60	1.81
Conventional Production=>Consumer Services	58	1.75
Administrative Services=>Consumer Services	50	1.51
Consumer Services=>Administrative Services	48	1.45
Software Provider=>Energy Services	44	1.33
Consumer Services=>Energy Services	43	1.3
Renewable Energies=>Administrative Services	42	1.27
Renewable Energies=>Sales Methods	42	1.27
Renewable Energies=>Infrastructure Operation	41	1.24
Renewable Energies=>Engineering & Construction	41	1.24
Conventional Production=>Renewable Energies	40	1.21
Energy Services=>Consumer Services	39	1.18
2018		
Co-occurrence	**Total amount**	**% of total**
Renewable Energies=>Prosumer	222	6.49
Renewable Energies=>Technical Services	157	4.59
Renewable Energies=>Energy Services	137	4.01
Prosumer=>Renewable Energies	132	3.86
Energy Services=>Sector Coupling	101	2.95
Renewable Energies=>Conventional Production	94	2.75
Renewable Energies=>Software Provider	92	2.69
Renewable Energies=>Consumer Services	69	2.02
Software Provider=>Energy Services	57	1.67
Conventional Production=>Consumer Services	56	1.64
Administrative Services=>Consumer Services	50	1.46
Renewable Energies=>Sales Methods	50	1.46
Conventional Production=>Energy Services	50	1.46
Consumer Services=>Energy Services	49	1.43
Software Provider=>Renewable Energies	49	1.43
Renewable Energies=>Administrative Services	46	1.35
Renewable Energies=>Analytics	45	1.32
Renewable Energies=>Engineering & Construction	44	1.29
Conventional Production=>Renewable Energies	42	1.23
Analytics=>Software Provider	41	1.2

Table .5: Co-occurrences of business model classes (2017 - 2018).

2019		
Co-occurrence	**Total amount**	**% of total**
Renewable Energies=>Prosumer	191	6.71
Renewable Energies=>Technical Services	117	4.11
Prosumer=>Renewable Energies	116	4.07
Renewable Energies=>Energy Services	97	3.41
Energy Services=>Sector Coupling	92	3.23
Renewable Energies=>Software Provider	76	2.67
Renewable Energies=>Conventional Production	59	2.07
Conventional Production=>Energy Services	53	1.86
Renewable Energies=>Sales Methods	50	1.76
Renewable Energies=>Consumer Services	48	1.69
Software Provider=>Renewable Energies	45	1.58
Administrative Services=>Consumer Services	44	1.55
Renewable Energies=>Analytics	44	1.55
Consumer Services=>Energy Services	41	1.44
Consumer Services=>Administrative Services	38	1.33
Renewable Energies=>Engineering & Construction	38	1.33
Energy Services=>Consumer Services	37	1.3
Software Provider=>Energy Services	37	1.3
Software Provider=>Analytics	35	1.23
Conventional Production=>Renewable Energies	35	1.23

Table .6: Co-occurrences of business model classes (2019).

.5 Co-occurrence Network Graphs

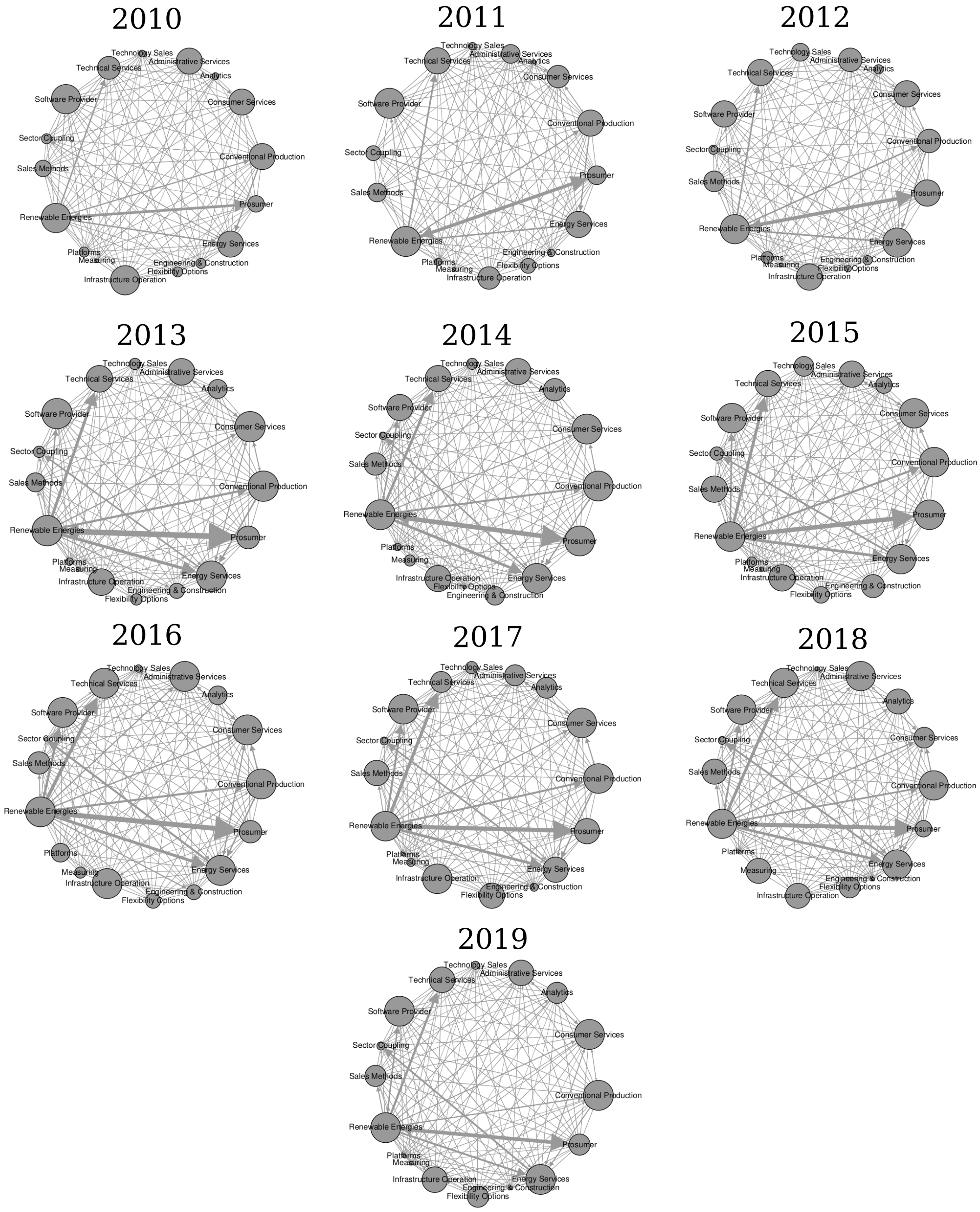

Figure .30: Co-occurrence graphs of the business model classes.